OUR BODIES

E. Desmond

CASSELL'S PRIMARY SERIES.

OUR BODIES:

AN

ELEMENTARY TEXT-BOOK

OF

HUMAN PHYSIOLOGY.

WITH 100 QUESTIONS FOR EXAMINATION.

BY

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AUTHOR OF "RIGHT LINES" AND "OUR HOUSES" (CASSELL'S PRIMARY SERIES); "LINEAR DRAWING" AND "PROJECTION" (CASSELL'S TECHNICAL SERIES).

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INTRODUCTION.

THE subject of Human Physiology is one of such interest and importance that it is not thought necessary to usher this little book into existence by an apology.

It is intended, first, to help school-teachers, by enabling them to place in the hands of their pupils a work from which they can prepare home lessons, and thus be better able to follow the lectures which may be given in the school; and secondly, to form an elementary text-book for those who are reading for examination in this subject.

The lessons are digests of the lectures I have given in the City of London Middle Class Schools, where I have found them sufficiently successful to justify me in recommending them to others.

My practice is to cause all the pupils to take notes, which they subsequently write out fairly, adding drawings of my blackboard illustrations.

I have been in the habit, before introducing the subject of the day, of calling on some boy in the class to read aloud his notes of the last lecture, by which much interest and emulation is excited.

In the illustrations I have avoided whole figures,

but all the parts are so arranged that the relative position of each is obvious.

In the text no opportunity is lost of teaching the subject with *regard to health*, and thus digestion, exercise, fresh air and ventilation, cleanliness, &c., are especially dwelt on.

A chapter on the Microscope is appended, with the view of encouraging the pupils to examine any objects of natural history which they may obtain, and to make their own observations thereon.

For much valuable assistance and instruction I am indebted to Dr. Marshall's and Messrs. Johnston's excellent diagrams, and to the works of Professor Owen, Dr. Carpenter, Dr. Shea, and M. Milne-Edwards.

This little book then is presented to teachers and pupils ; it treats not of man's works, but of God's, and thus the subject must ever command an attention higher than those which merely appeal to the intellect ; and as the being here treated of is the only one we know of in all animal creation who can elevate his thoughts to heaven, let me hope that in showing "how fearfully and how wonderfully we are made" I may sow some seeds which may fructify in the new soil in which it is sown, and bear fruits of gratitude to the merciful Creator of all.

ELLIS A. DAVIDSON.

OUR BODIES.

In a former little book* I have spoken to you of the way in which a house is put together, and of some of the materials employed in it.

I now intend to give you a few lessons concerning a structure more wonderful than any that man can build—the house which God has created to be the dwelling-place of the soul during its life on earth; and I am sure that when you know how wonderfully we are made, you will be led to think of the Great First Cause, the Mighty Creator of all, and that you will try to render yourself worthy to dwell in the beautiful mansion which He has provided for you.

The Skeleton.

The human body is supported on a framework called the skeleton, which is made up of about 198 bones.

Bone is a hard and strong substance formed principally of carbonate of lime, phosphate of lime, and gelatine.

* "Our Houses," published by Cassell, Petter, and Galpin, price 1s.

The lime is called the **Mineral** portion—Minerals you will remember are substances dug out of the earth, forming rocks ; and carbonate of lime we are very familiar with, as it is only limestone and chalk.

Phosphate of lime comes from rocks in which a great many remains of animals exist.

But you will perhaps ask how does the lime get into our bones ? Well, it is contained in many articles of our food, and also in water, in this way it mixes with the blood, and the blood carries it into the bones, in a manner which I will explain to you presently.

The gelatine in bones is called the **Animal** portion, and is the substance which forms the jelly and glue.

Of course you know that bones are of very many different shapes, but still they may be classed into three sorts:—

The **Flat**, such as the **Shoulder-blade** ;
The **Short**, such as those in the **Wrist** ;
The **Long**, such as those in the **Legs**.

All these different bones are so arranged that each one performs exactly the duties required of it. They are nourished or fed (that is, the new particles which are to assist their growth are brought to them) by the blood in a most wonderful manner.

To explain this, let us take a sketch (Fig. 4) of a portion of a thigh bone, highly magnified, here you will see that the whole of the top is covered with small rings and openings. These openings are the mouths of tubes which come from the outside of the bones. Now around each bone is wrapped a strong membrane or skin, called the

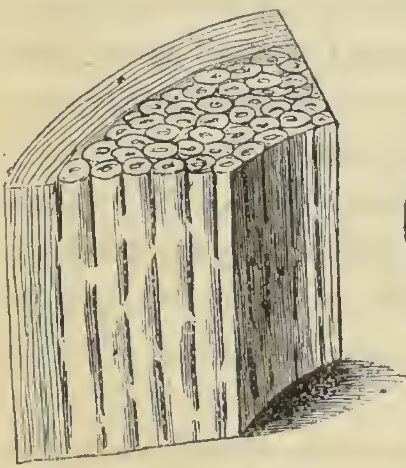


Fig. 4.

Fig. 5.

Pe-ri-os-te-um, the name of which is derived from two Greek words, "*Peri*, about, and *Osteon*, a bone." In this membrane there are a great number of blood-vessels, which becoming very small and hair-like, enter the small openings in the bones and travel through the tubes I have described.

(Fig. 5). Around each of the small tubes are arranged the layers forming the bone, and between

these layers are small open spaces, marked in black in this drawing, called **Lacunæ**. These are joined to each other, and to the canal which they surround by other and still smaller openings, called "**Can-al-ic-u-li,**" and thus the nourishing fluid passes from the blood-vessels into the very substance of the bones.

The tubes through which the blood-vessels travel are called the "**Haversian Canals,**" having been discovered by Havers, a very learned doctor, who lived in London about the year 1690.

You can for a very trifling sum buy small pieces of bone, cut lengthwise and across, ground down until they are so thin that you can see through them, and mounted between two pieces of clear glass.

You will thus be able by means of a microscope to study the structure I have described. I am anxious that you should learn to examine and think for yourself, and will, therefore, before closing this book, give you some information about Microscopes and the way to use them.

You can very easily separate the mineral and animal portions of a bone, so as to examine the manner in which each is placed.

Take a little block of bone and place it on a

piece of tin, rake out some of the fire between the grate and the first bar, so as to form a sort of oven, and put your bone on its little tray in this. The heat will gradually burn away all the gelatine, leaving only the earthy portion. You must then with the tongs draw out your tray, and will be able to see the structure very clearly, but you must be careful to touch the remains of the bone very lightly, as it will easily crumble to pieces.

Again, take another piece of bone which has not been cooked, and place it in an old cup or jar; buy at a druggist's a little "muriatic acid," mix with about twice its quantity of water, and pour it over the piece of bone. This will gradually dissolve the earthy portion and leave only the gelatine, which will be so soft that it may be easily cut, but it will be of the exact shape of the bone, and if melted down in water would form *glue*.

The human frame is divided into

The **Head,**
The **Trunk,** and
The **Limbs.**

You will of course understand that by the head is meant the skull containing the brain, which is the organ of all the senses.

The Trunk is the part usually called the "body,"

and in it are placed the organs by means of which our food is digested, by which the blood is formed and carried throughout the system, and by which we breathe.

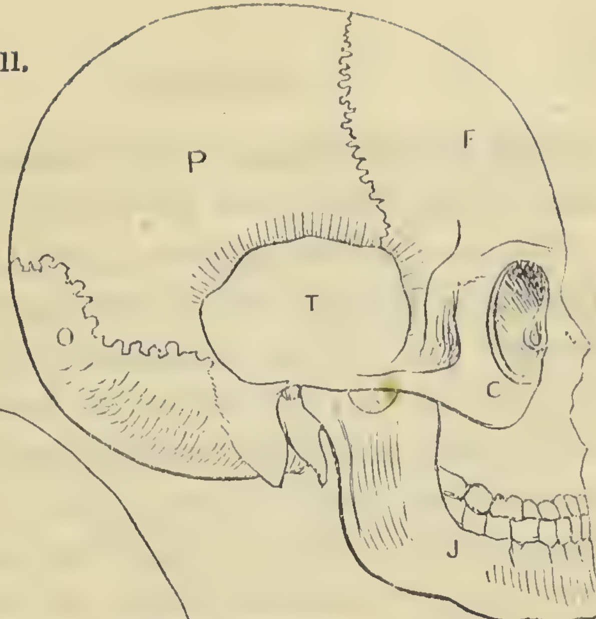
The Limbs are the arms and legs; and the ends of them—that is, the hands and feet—are called the **Extremities**.

The Skull.—The Skull consists of several bones, which are united in a manner somewhat like the "dovetail" used by joiners, but it is far more complex, the peculiar mode of joining extending throughout the whole thickness, thus locking the parts together so firmly that it is impossible to separate them; in fact, additional strength is given at these joints by the bones being thicker there than at any other part. These joints are called **Sutures**, and are shown in the view of the skull here given (Fig. 1).

Side View of the Skull.

The following are the principal bones composing the skull:—F, the **Frontal bone**, or forehead. It is this bone which gives a beauty of form and a dignity seen in no other animal in creation. In the skulls of Europeans, the forehead and front of the face are nearly in an upright line, which, you

Fig. 1.
Human Skull.



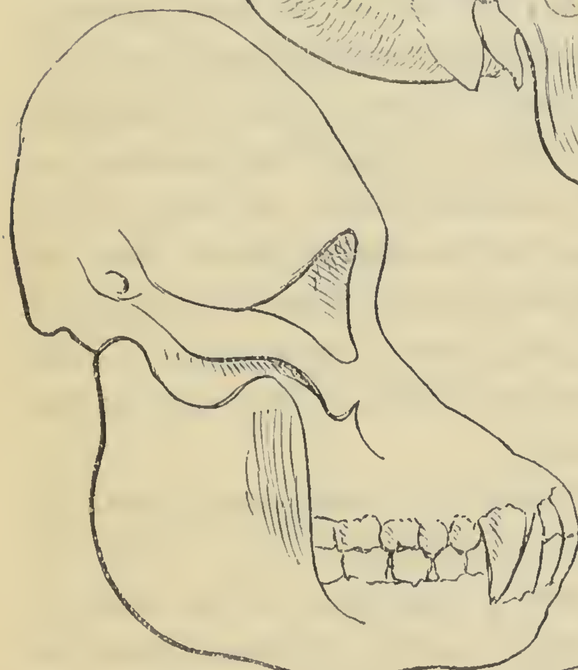


Fig. 2.
Skull of Orang-Otang.

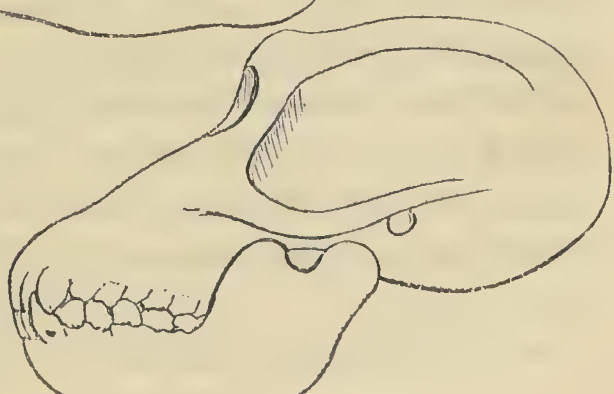


Fig. 3.
Skull of Chimpanzee.

will see, is very different in the lower animals, such as the Orang (Fig. 2) and the Chimpanzee (Fig. 3).

Next are the **Parietal** bones, marked P in Fig. 1. These form the walls of the skull, and meet at the crown. They join the **Temporal** bones, T, which form the sides at the part of the head known as the temples; and at the back and lower part of the temporal bone there is a hole, outside of which the **Ear** is placed. This opening is the entrance to a canal which is hollowed out in the bone, and in which the organ of hearing is placed; from this the nerve passes which conveys sounds to the brain.

As I intend giving you a lesson on the Ear and the sense of hearing, I will not say more on that subject in this place.

The parietal bones join the **Occipital**, which forms the back and base of the skull.

Returning now to the front of the head, we observe two large cup-like cavities called the **Orbits**, in which the eyeballs are placed; above each of these there is a strong ridge, which is covered by the eyebrow, and this serves greatly to protect the eye (which is a most delicate organ) from injury, as it lies sheltered by the surrounding walls.

At the back of each orbit there is a hole, through

which the nerve of sight carries the form which is reflected on the eye, to the brain, and this is how we see.

At the inner corner of the orbit there is a small canal passing down into the nose; this is called the **Lach-ry-mal duct**, or tear canal.

To understand the use of this duct, you must be told that above the outer corner of the eye there is a little gland called the "tear bag," which, as its name will tell you, contains tears.

Glands are soft masses made up of a number of small cells or bags, or of a great quantity of fine tubes twined together; their use is to secrete—that is, to gather—certain liquids which separate from the blood.

The purpose of the liquid which gathers in the tear bag is to moisten the eyeball as it moves about, and as the eyelids open and close over it.

When this duty has been performed, the surplus moisture passes down the lachrymal canal into the nose; but sometimes, owing to pain or deep feeling, a greater quantity of the liquid than is required rushes to the eye; and as this comes more quickly than it can be carried off by the canal, it overflows and rolls down the face in the shape of tears; this sometimes takes place from the effects of a cold.

I shall be able to tell you more about this when speaking of the eye itself further on.

Under the Orbits we have the **Cheek Bones**, C H, which form their lower edge, and between these are the bones forming the upper part of the **Nose**, N ; the lower part of the nose is not composed of bone, but of cartilage or gristle.

Next, we come to the **Upper Jaw**, containing, as you know, some of our teeth, the rest being fixed in the **Lower Jaw**, J, which moves by means of a hinge-joint just in front of the opening of the ear.

The manner in which the Lower Jaw works against the upper differs according to the habits of the various animals, and the food they live on ; thus, the jaws of the **Car-ni-vora** (animals which live entirely on flesh, such as the lion, tiger, cat, &c.), have an *up and down* movement, by which the sides of the back teeth pass closely against each other, and so cut up the meat exactly as sharp shears would do.

But oxen, horses, &c., which belong to the group called **Herb-i-vora** (animals that live on herbs and things which grow), have what is called a *lateral* or sideway movement, and thus their food is ground up between their flat-headed teeth as in a mill (in fact, the back teeth in all animals are called *molar* or mill-like). *See* page 44.

You will understand what this movement is like if you place your open hands together, as if you were going to clap them, then, keeping the wrists still touching, move the palms from left to right over each other.

But no doubt you have seen a cow taking its meals, and have you not noticed how, when lying on the grass with her eyes closed, the very picture of comfort, she grinds up the grass which she cropped sometime before, and which having been well soaked in her paunch has come up again to be properly chewed? You will then have noticed how the lower jaw moves from side to side, to an extent which would certainly make Miss Pussy's jaws ache for a long time if she were only to attempt it.

In the **Rodents**, that is the gnawing animals, such as the beaver, whose mode of building requires it to cut through branches of trees, and the Squirrel, who has to bite through the hard shells of nuts, the jaws do not move sideways, but have a forward and backward action, and as the ridges on their back teeth are set in opposite directions, they act as files, and so grind down the hardest vegetable matter.

Now **Man** is called an **Omnivorous** animal, that is, one which can eat any sort of food, whether

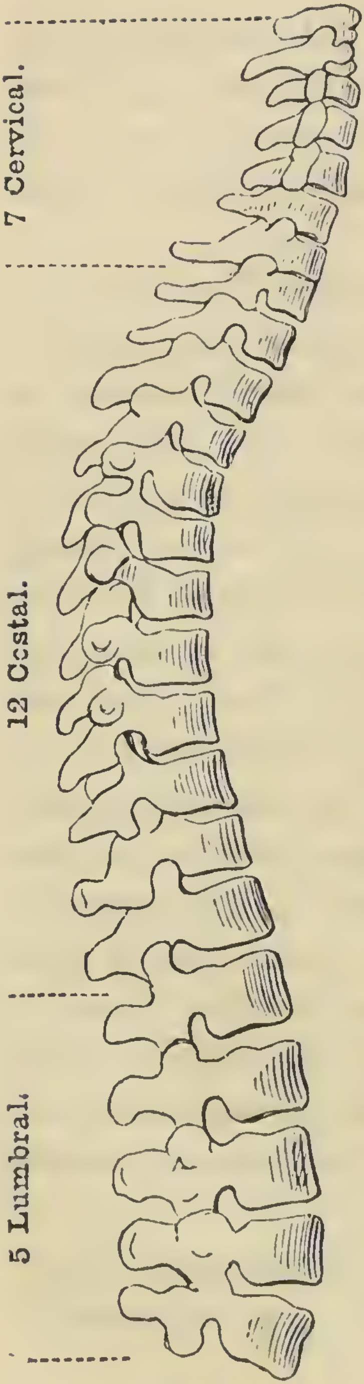


Fig. 6.

animal or vegetable, and thus we have the power of moving our jaw in *all* the ways described. We can either simply open and shut our mouth, or we can move our lower jaw side-ways or forward, just as we desire, thus showing how wonderfully the construction of every creature is adapted to its habits and mode of life.

The Trunk.

The most important portion of the Trunk is the **Spinal Column,** or, as it is more properly called, the vertebral column, as it is made up of a number of separate bones called *vertebræ.*

These bones are named according to the places they occupy, as follows (Fig. 6) :—

7 **Cervical,** or of the neck.
12 **Costal,** or of the ribs (sometimes called Dorsal).
5 **Lumbral,** or of the loins.
24

As these move on each other by a sort of hinge-joint, they are called the **twenty-four movable vertebræ.** They rest on a large flat bone called the **Sacrum,** S, Fig. 8, which has been made up of five separate vertebræ, but which have now no motion; and these are followed by four small bones called **Caudal,** c, or of the tail, also fixed in man; but in other animals the bones forming the tail are more numerous, and are movable.

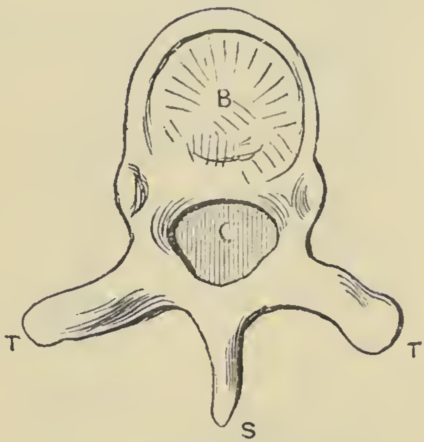


Fig. 7.

The immovable vertebræ, then, are—

5 **Sacral,** or belonging to the sacrum;
4 **Caudal,** or of the tail;
9

and you will thus see that the **Human vertebral**

column consists of **twenty-four movable and nine immovable** bones; **total, 33.**

Each separate vertebra consists of a solid piece of bone called the body, B, Fig. 7; a back, in which is a canal, or tube, C. Through this canal the **Spinal Cord,** which is a lengthened portion of the brain, passes.

The vertebræ have strong pieces of bone called "transverse processes," T T, projecting from their sides, and others from their back. These, which you can feel at the back of your neck, are called the "spinous" processes, S; and this is why the vertebral column is sometimes called the *spine.*

Several large fleshy bands, or cords, the purpose of which is to bend the back, are fixed to these processes. These bands are called muscles, and we shall speak of them in another lesson.

We are protected against any ill effects which might arise from sudden shocks or "jars," by which the vertebræ might be fractured and the spinal column be injured, by cushions of cartilage (see C, Fig. 8, annexed) placed between the movable vertebræ.

By long pressure of the bones on these cushions they become flattened, and the body thus bends forward. During rest, whilst lying down at night,

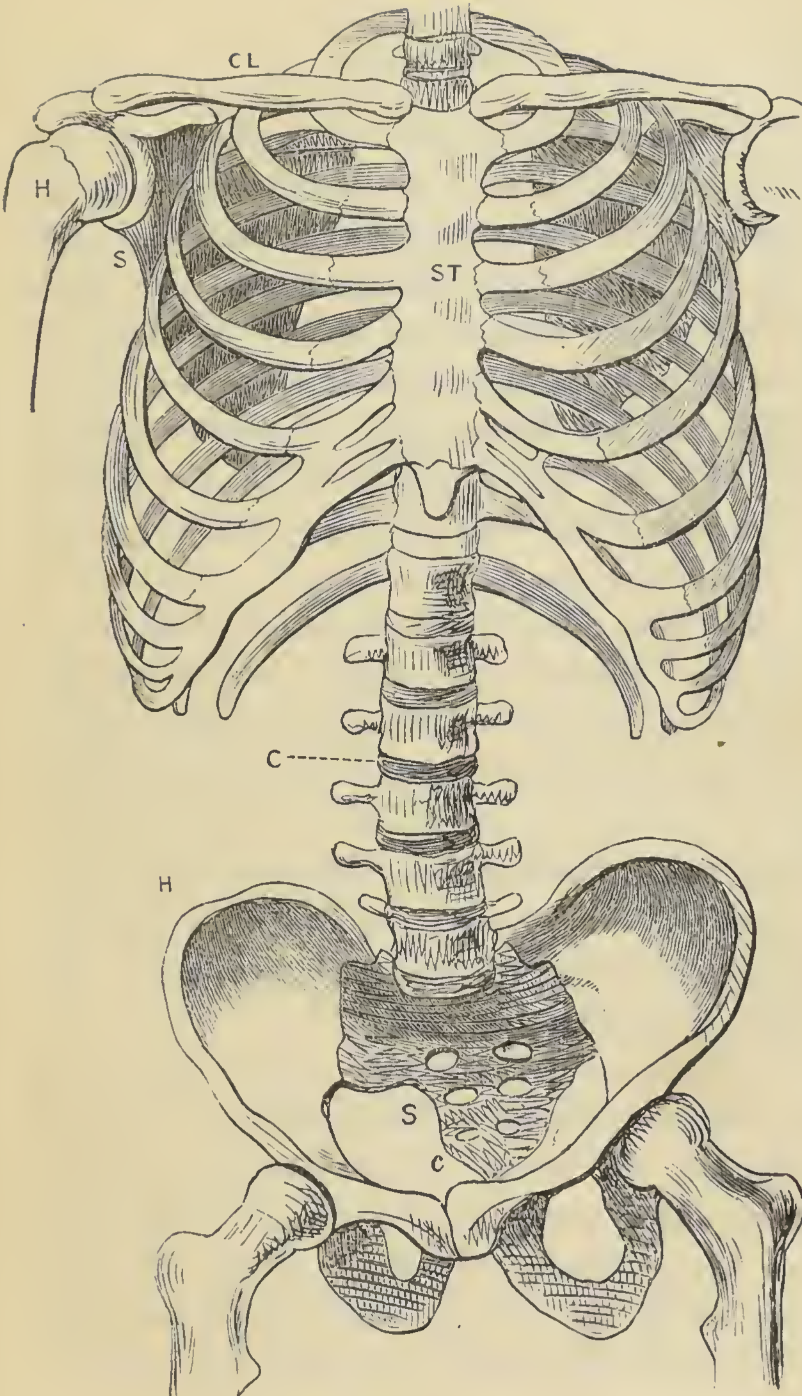


Fig. 8.

the cushions, being elastic, recover their form, and thus a man is about half an inch taller in the morning than he was when he lay down the night before. In very old persons, however, the pads do not recover their elastic quality, and this will account for the stooping form of the aged.

The annexed drawing (Fig. 8) shows the trunk complete, and from this you will see how all the other parts of the skeleton spring from, and are dependent upon, the vertebral column.

The **Ribs** are slender but strong bony hoops, which are situated at the upper part of the trunk.

They are twenty-four in number, namely, twelve on each side, and are all attached to those bones of the spinal column which you will remember are called *costal* vertebræ; but although they are *attached*, they are not *fixed*, but work by a joint, the purpose of which will be explained to you in the lesson on breathing.

You can examine how the ribs of animals are attached to the vertebræ when you have a mutton chop; for you know a mutton chop is a rib of a sheep, and a sheep is a *vertebrate* animal—that is, one having a vertebral column. When you have removed all the mutton, you will find that there will remain a long thin bone, which is a part of a

rib, and a block of solid bone at the upper end, which is a piece of a vertebra. Now if you clear away all remains of ligament (the bright bluish bands which hold bones in their places) you will be able to move the rib in the vertebra, and in fact, to separate it entirely.

The fourteen upper ribs, namely, seven on each side, come right round from back to front, and are joined to a flat narrow bone called the **Sternum,** or breast-bone, S.

The bones of the ribs are not, however, carried quite up to the breast-bone, but they end in cartilage, or gristle, and by this means they are joined. I have marked this joining in the drawing.

These fourteen ribs, which are united to the Vertebræ at the back, and to the Sternum in the front, are called **True Ribs.**

The next six ribs, that is, three on each side, are attached to the vertebræ at the back, but not to the breast-bone. They come partly round, and then each is joined by cartilage to the one above it; and the last four ribs (two on each side) are joined at the back only, but are not in any way attached in the front. The whole of these last five pairs of ribs, that is those which are not fastened to the breast-bone, are called "**False Ribs**;" and the

last two pair of these, which are not joined in front at all, are called "**Floating Ribs.**"

The twelve Costal vertebræ, the twelve pairs of ribs, and the breast-bone, form the framework which encloses the great cavity or chamber called the **Thorax.**

In the Thorax are placed the Heart, Lungs, and other very important organs; and you will at once see how well all these are protected by the beautifully constructed bony cage by which they are surrounded.

But this framework, although strong, is not *rigid*, for, owing to the joints at the back, and the cartilage in the front, it can rise and fall so that the space within may become enlarged, and thus room may be allowed for the action of the organs it contains.

The lower part of the trunk is formed by two large bones called the **Haunch** bones (or hips), H, which join on to the **Sacrum.** These together form the **Pelvis** (or basin), in which many very important organs are contained.

The **Trunk**, then, consists of the **Vertebral column**, made up of **twenty-four movable** and **nine immovable bones**, of **seven pairs of true and five pairs of false ribs**, and of the **haunch bones.**

The Limbs.

The Upper Limbs, that is the **Arms**, are attached to broad flat bones, called the **Shoulder-blades**, S, which are triangular (three-sided) in shape, and placed at the back of the ribs. From the upper corner the bone turns round and so forms the shoulder, and into this a bone is joined, called the **Clavicle**, C, or **Collar-bone**, the other end of which works in a hollow in the top of the breast-bone.

The name of this bone is derived from that of a key which the Romans used, which seems to have been of this shape. The purpose of the collar-bone is to keep the shoulders apart, and to keep them firm when the upper limbs are being used, hence we find that in animals such as the horse it is absent, for the weight on a horse's fore-legs (which are *his* arms) serves to keep them as far apart as is required; in a lion or cat, whose modes of life compel them to squeeze through bushes and to spring and jump, the collar-bone is but very small, and is not fixed, so that their shoulders may not be kept apart; but in birds not only is this bone very strong, but the two are joined at the bottom so as to form one bone, shaped something like a V, and which is known by the name of the Wishing-bone, or Merry-thought, for you know the bird's wings

are its arms, and of course in flying these have to be constantly worked, and this could not be done unless the shoulders were kept firmly apart. The clavicles enable man to raise weights, and in very many ways give strength and firmness to the arms.

Now you must understand that the bones belonging to the upper limbs correspond with those in the lower, that is, there are the same sort of bones in each. Thus the haunch-bones already spoken of answer the same purpose in regard to the legs which the shoulder-blades do to the arms. At the one end of the shoulder-blade there is a very shallow cup, called the **Glenoid cavity**, in which the head of the upper bone of the arm works, and on the side of the haunch-bone there is a deep cup in which the head of the thigh-bone moves. The cavity which receives the arm-bone is shallow, to allow of our moving our arm about very freely, whilst the deeper cup in which the thigh-bone moves assists in affording a firm rest for the body, the great freedom of action required by the arms not being necessary for the legs.

The upper bone of the leg, which is called the **Femur**, or thigh, marked Fem. in Fig. 9, corresponds with the upper bone of the arm called the **Humerus**, H., in Fig. 10.

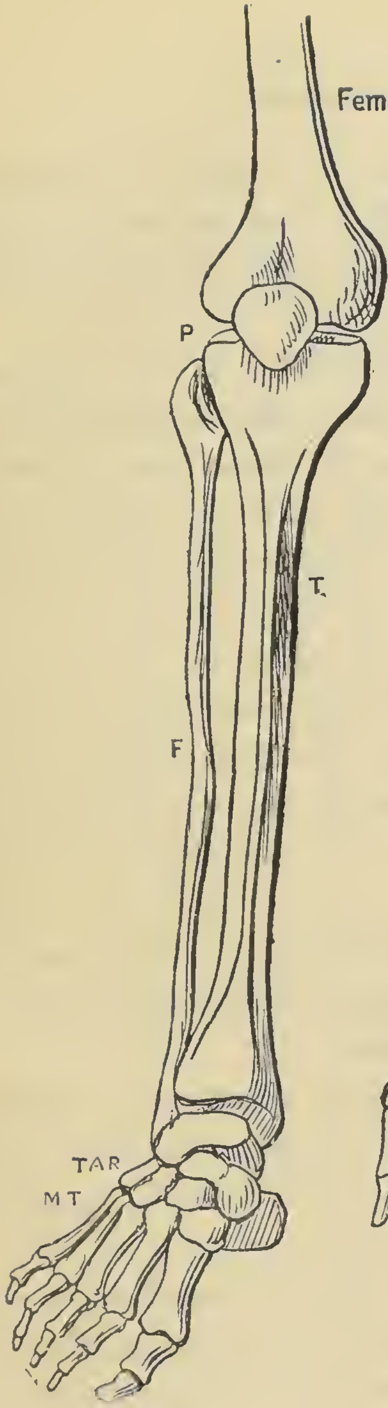


Fig. 9.

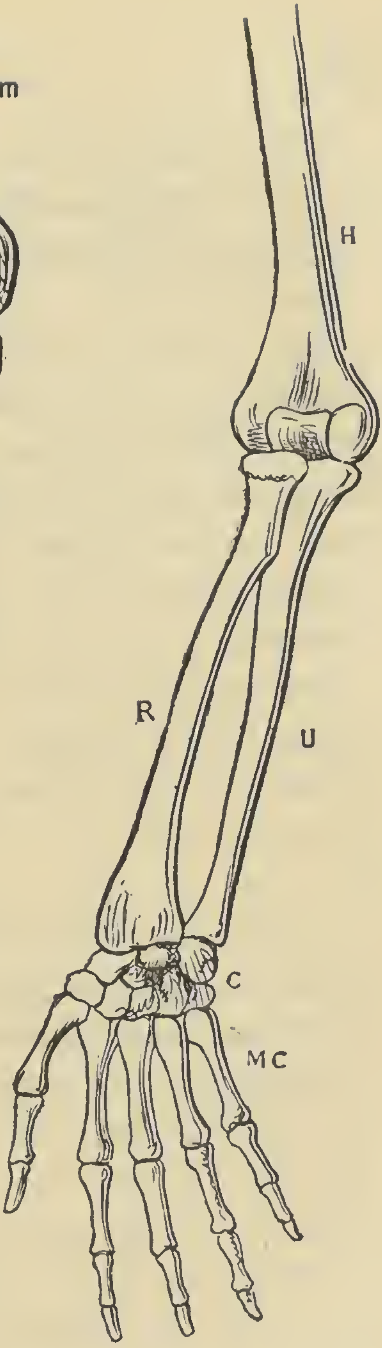


Fig. 10.

The Bones of the Leg and Foot compared with those of the Arm and Hand.

The heads of both of these are shown in Fig. 8, so that you will be able to see the way in which they are attached to the bones in which they work.

Fig. 9 shows the lower bones of the leg, and Fig. 10 shows the bones of the fore-arm, and you will see that there are the same sort of bones in each, and that as the limbs become more distant from the trunk, they are formed of two bones instead of one; this gives lightness combined with strength.

The larger bone, T, of the lower leg is called the **Tibia**; it is three-sided, and its sharp edge in front is called the shin; the bottom of this bone forms the inner ancle, and it rests on a large bone in the foot.

The smaller bone attached to the side of the **Tibia** is called the **Fibula**, F. and the lower end of it forms the outer ancle.

At the joint of the knee there is a round bone, called the **Patella** or knee-pan, P, which gives firmness to the leg, and assists in the action of the muscles which pass over it.

The fore-arm corresponds in structure with the lower leg, being formed of two bones, of which the largest is called the **Radius**, R, and the other the

Ulna, U. The upper end of the Ulna forms the sharp point of the joint called the **Elbow.**

The Radius is much larger at the bottom than at the top, and to the larger end of this, the bones forming the wrist are attached.

This bone is annexed to the Ulna in such a manner that it can glide nearly round it, and this gives us the power of twisting our hand. Hold your arm out quite straight with the back of the hand uppermost, and you will see that you can turn it so that the palm is upward *without moving the joint at the shoulder.* It is this motion which is going on in the arm of a carpenter when he is boring a hole with a gimblet or driving in a screw with a screw-driver.

The ends of the limbs, namely, the feet and hands, are called "**The Extremities,**" and, as in the limbs, there is the same arrangement in each.

In the foot we have three sets of bones, called the **Tarsus** or *instep* (TAR), the **Meta-tarsus,** which forms the front part of the foot (M T), and the **Toes.**

In the hand we have the **Carpus,** C, or wrist, which corresponds with the Tarsus of the foot. Next come the bones of the **Meta-carpus** or hand (M C), which are similar in arrangement to the

Meta-tarsus, and you will easily see that the fingers correspond with the toes.

There are *seven* bones in the Tarsus, one of which, a very large one, forms the heel, and on the bone over this the Tibia rests.

In the Carpus there are *eight* bones, all of which are wedge-like in form, the narrow ends being placed inwards; so that the wrist is shaped like an arch, and whilst it is very strong, it is still capable of the most delicate movements.

The Meta-tarsus consists of five bones, and the Meta-carpus of five; in fact, these two sets of bones are very nearly alike in shape as well as in number, the inner one of each being rather thicker than the other four.

The toes and fingers correspond exactly in their number and the character of their bones, the great toe holding the same position in the foot as the thumb does in the hand, and each of these has one bone less than the other toes and fingers; thus each of the toes is made up of three bones, whilst the great toe has but two, and each of the fingers is composed of three bones, but the thumb has only two.

The foot of man, is indeed, very wonderful in its construction, being formed on the true arch principle (which you may perhaps recollect I explained to you

in another little book called "Our Houses"). All the bones of the Tarsus are like so many stones in the arch of a bridge, and thus press closer together when the weight of the body rests upon them, the piers of the arch (that is, the parts on which it rests) being formed by the toes in the front and the heel at the back. This arch is not only very strong, but, owing to the toes being formed of several bones, the whole foot is elastic, and forms a spring by which the body is moved forward without the other bones being shaken or jarred against each other. In animals whose mode of life renders it necessary that they should bound after their prey, and jump or spring from trees and other high places, this elastic character is increased, and they are provided with pads under each joint, which serve to break the shock their frame would otherwise receive. I have no doubt that you have noticed how very quietly and nimbly a cat runs, and if you could manage to examine her paws when she has "gloves on," you would see that this is owing to little black cushions which she has under them.

The arch in the foot, too, serves to lodge and protect the numerous blood-vessels and nerves with which it is supplied, as well as the **Tendons** (which are thin bands of cartilage) by which the toes are moved.

The human foot differs from that of the gorilla, or orang, or any of the monkey tribe, by being placed flat on the ground, so that we can walk with our bodies perfectly upright; but if you look at a monkey *trying* to walk in an erect position, you will see that he *only rests* on *the outer edge* of his foot, and as this cannot last long, he is soon very glad to come down on his hands or knuckles, or to catch hold of anything he can to support himself.

The hand of man differs from that of the monkey tribe in having the thumb much longer, and in its superior power of grasping very small objects. If you bend all your fingers and your thumb, you will be able to make the *tips* of all the five meet, but a monkey cannot do this, he can only bring his fingers together as if he were going to take a pinch of anything, his long and slender fingers being more adapted to catching hold and swinging from branches of trees, and as I have already told you he uses them for walking as well—whilst the beautiful construction of man's hand is such that he can perform the most delicate and refined operations with it.

Let us now count up the various bones of the arm and leg of which we have been speaking. If you refer to the drawing you will fix the shape

and place of each on your memory, and will understand how they correspond with each other :

Bones of the Arm and Hand.	No. of Bones.		Bones of the Leg and Foot.	No. of Bones.
Humerus, or Upper Arm	1,	corresponding with	Femur, or Thigh	1
			Patella, or Knee Pan	1
Radius, Ulna (Lower Arm)	2	,,	Tibia, Fibula (Lower Leg)	2
Carpus (Wrist)	8	,,	Tarsus (Instep)	7
Metacarpus (Hand)	5	,,	Metatarsus (Foot)	5
Fingers, 4 with 3 bones (12), Thumb (2)	14	,,	Toes, 4 with 3 each (12), Great Toe (2)	14
	30			30

Of Joints.

There are two principal kinds of joints, the fixed and the movable.

You will remember that I told you different bones forming the skull are joined by jagged saw-like edges, which grow into each other from early infancy ; this will at once show you what is meant by a fixed joint.

Movable joints are of two kinds: first, the **Hinge**, such as that at the elbow; and, second, the **Ball and Socket**, like that at the shoulder, where the rounded or ball-like head of the arm-bone works in the Glenoid cavity. The bones of the fingers move on each other in this way as well.

All these joints are liable to dis-lo-ca-tion, that is, being "put out" of their place. Owing to the shallowness of the cavity at the shoulder, this joint is frequently dislocated; and this sometimes happens to the thigh, but not so often, as the cup in which the Femur moves is much deeper.

Joints which have been dislocated should at once be "set;" but now that you have seen how liable you are to accident, I hope you will be careful not to indulge in too violent or rough exercise, by which you might not only dislocate the joints, and so in time weaken them, but might also fracture the bones and become crippled for life. Many children have the habit of pulling their fingers so as to make them "crack;" this is exceedingly wrong, for it is to a certain extent pulling the joints out of their sockets, and by doing this they wear away the edges of these sockets, and may so loosen the joints as to cause permanent injury.

The joints are kept lu-bri-ca-ted, that is, "greased,"

by a liquid called "**Syn-o-via**," which flows out of small bags placed between the bones. When we endure great fatigue, or take violent exercise, the synovia is used up faster than it is supplied by the system, and rest becomes necessary in order that a fresh quantity may gather again.

How our Bodies are Moved.

The bones of the skeleton, which have thus been described, have of themselves no power of motion, but are acted upon by numerous bands and cords called **Muscles**.

Muscles are made up of bundles of fleshy strings called "fibre," kept together by very thin membranes; and these bundles unite at their ends, and are joined by white glistening cords called **Tendons**; these are sometimes very long, and thus the muscles can act on a part which may be at a distance from them.

You will understand this if you look at Fig. 11, page 39, in which you will see that the muscles which move the fingers and toes are in the arm and leg, but send out their tendons into the most distant points.

If you look at a piece of beef or mutton which has been cut across, you will see the ends of the

bundles of fibres; for muscle constitutes what we call *flesh*, and if you were to examine a piece of it through your microscope, you would see all the bundles of fibre separately, and between them the tiny blood-vessels which nourish them; I dare say you have seen a piece of meat, when it has been boiled too much, fall into separate strings, which are the fibres of which the muscles have been formed.

Muscles are called **Voluntary**, or such as are under the power of our will; and **Involuntary**, or those over which we have no control.

The voluntary muscles are those concerned in motion, such as those in the leg or arm, for you know we can move either of our limbs, or let them rest, just when we wish.

The involuntary muscles are those by which the action of the internal organs are carried on—such as the movements of the heart, lungs, and intestines—for of course it is necessary that all these should go on performing their proper work even whilst we are asleep.

We have, however, a certain amount of power over some of the involuntary muscles; thus, we can "hold our breath"—that is, we can stop the motion of the muscles concerned in the action of breathing for a very short time. The muscle which

moves the eyelid must be considered as something between the voluntary and involuntary, for you will remember that, although "winking" goes on without any effort of ours, still we can keep our eyes open without winking for a moment, and we can close our eyelids, and so stop the action altogether.

The muscles are arranged in the body so as to oppose each other in action. Thus, when one set, called **Flexors** (or benders), are drawing a limb up, another, called **Extensors**, are at full stretch, and in a state of resistance, and the moment the will ceases to govern the Flexor, the Extensor draws the limb back again, and extends or straightens it. This action will be understood on looking at Fig. 11, in which B is called the Biceps, which draws the arm up, whilst a muscle at the back of the arm, called the *Triceps*, is ready to draw it back and straighten it again. In this plate also will be seen the great **Pectoral** or chest muscle, P, which draws the arm forward and downward; and the **Deltoid**, D, or muscle of the shoulder, which raises and otherwise moves the arm. The arm is drawn backward by muscles at the back of the shoulder.

Both ends of a muscle are never attached to the same bone. The part at which it is fixed, and to

which the movable bone is to be drawn, is called the **Origin**; and the part at which they are attached to the bone which is to be moved is called the **Insertion.** A muscle acts by contracting in its fleshy part, for the tendons, though flexible—that is, able to be bent—are not *elastic*, they do not stretch. The consequence of this contraction is to make the muscle for the time thicker in the middle; this you may feel on taking hold of the Biceps muscle when bringing your fist up towards the shoulder.

We also find muscles called Supinators, such as S in Fig. 11, the purpose of which is to turn the palms of the hands *upward;* Pronators, such as P, which turn the palm *downward;* and Abductors, which draw one part *away from another*, as in moving your forefinger away from the others.

I have told you that the tendons which move the fingers are the con-tin-u-a-tions of muscles having their origin in the arm, and you will no doubt remember, that when you have hurt your finger, you have felt the pain all up the arm. Now the tendons by which the toes are moved are constructed in the same manner: they are the ends of muscles which are fixed in the leg near the knee, and it is by the contracting of these muscles that the tendons

draw up the fingers and toes. Here a beautiful arrangement claims our attention, the necessity for which you will at once see if you try to move your fingers by means of strings or cords.

Tie loops in four pieces of tape, and in these place the tips of your fingers; gather all these tapes in your other hand, and holding them near the elbow, gradually tighten them. You will then see that, although you succeed in drawing the fingers up, you could not endure such an arrangement, for the tapes would form straight lines from the tips of the fingers to the upper part of the fore-arm, and would become something like the string of a bow, doing away altogether with the hollow of the palm, and causing such inconvenience as to render the hand all but useless.

Again, you will remember that in the reign of Richard II. shoes were worn with such long peaks that the toes of them had to be fastened to the knees with silver chains, and you can imagine how this must have interfered with walking and all other movements; but only think how we should feel if the tendons which are inserted into the toes at one end, and near the knee at the other, proceeded to join these two points in a straight line! We should neither be able to wear boots, shoes, nor stockings,

and the tendons would be in constant risk of danger.

All this is guarded against in the most wonderful manner. As the tendons pass along the fingers and toes, they are carried under little bands or rings of cartilage, which confine them at the joints, but still allow of motion; and when they reach the ancle or the wrist, they are all gathered by a sort of *natural bracelet*, under which they glide, being greased by a fluid similar to the synovia, which, you remember, oils the joints of the bones. These bracelets are called the **Annular** (or ring-like) **ligaments**, and are shown at A on the wrist in Fig. 11, and there is a similar one in the foot.

Muscles increase in size and strength according to the use made of them, as exercise of any limb causes the blood to flow to it, and so it receives additional nourishment. Thus, in a man whose occupation causes him to sit all day, whilst working with his hands, the muscles in the arms will become larger and stronger than those in the legs; whilst in a man who walks much, but does not work with his arms, the legs will increase in the greater proportion.

We thus see that proper exercise after our daily work is over is highly necessary in order that our

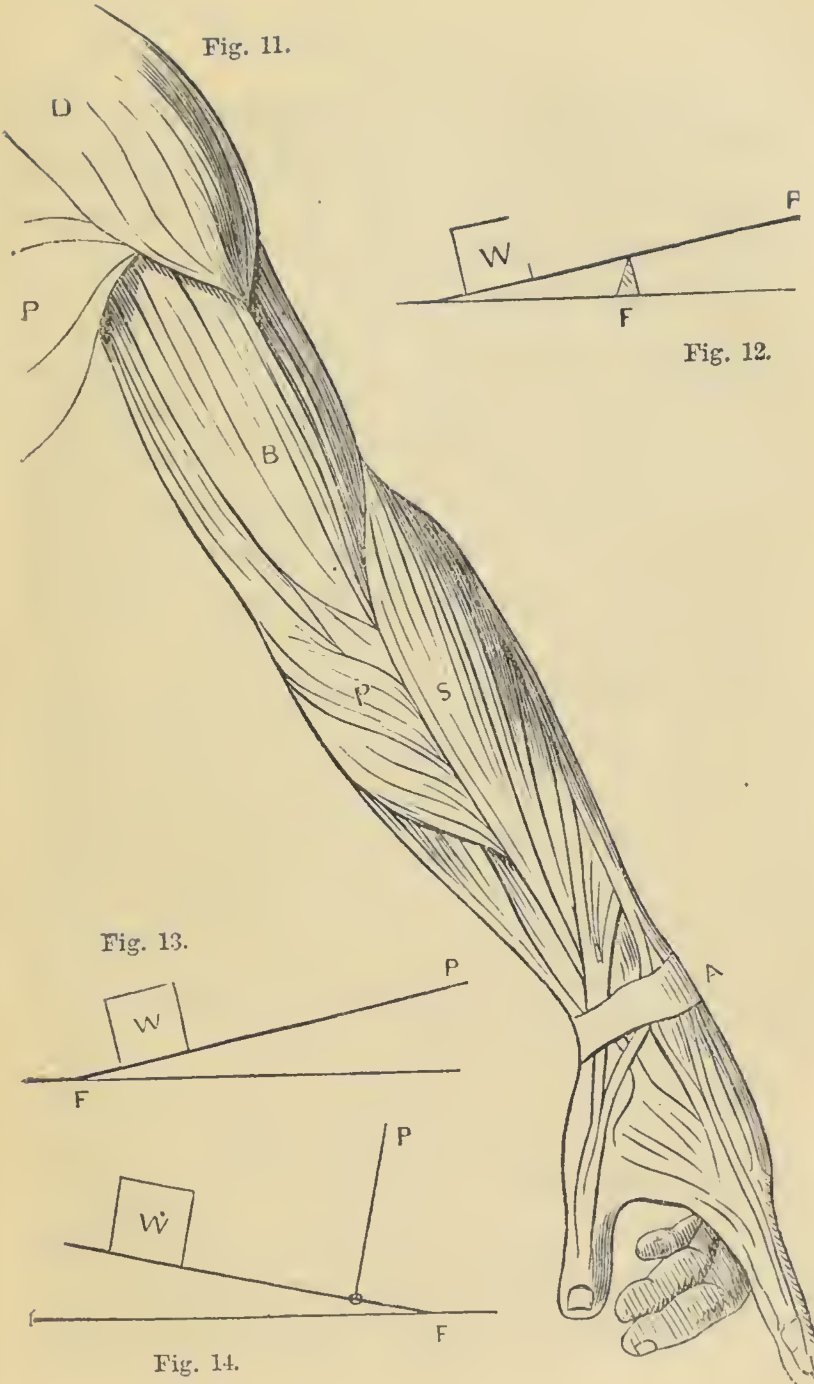


Fig. 11.

Fig. 12.

Fig. 13.

Fig. 14.

whole frame may be kept in proper action; and in young people this is most important, in order that each part of the body whilst growing may be properly developed and strengthened.

The same principles which I have thus endeavoured to show you acting in the arm and lower leg, are also applied in all other parts of the body. Thus, if you put your hand to the side of your neck, you will feel a strong muscle, called the **Mastoid,** which turns your head round; and on the other side you may feel the one which draws the head back again.

These muscles start from the top of the breastbone, and are inserted into the skull just at the back of the ears. When acting together, they draw the head downward, and whilst doing this they are opposed by a larger triangular muscle, called the **Trapezius,** which covers the upper part of the back just like a small shawl, and is inserted into the back of the head.

Of the Levers in our Body.

A lever is a bar or rod by which a weight is moved. When you put the poker into the fire, and press the knob which you are holding, downwards, then the lump of coal in the stove against

which the poker presses will be raised; then the coal is called the **Weight**, and your hand pressing on the knob is called the **Power**, and the part of the bar on which the poker rests is called the **Fulcrum**; and thus you see you have learnt the *first* order of levers, namely, that in which the weight is at one end, the power at the other, and the *fulcrum between* them (Fig. 12). This sketch will show you the position of the weight, the power, and the fulcrum in this order of levers.

Again, watch a man pushing a wheelbarrow along. The *weight* is in the *barrow*, and of course the *power* is in the man's hands, the fulcrum (that is, the point on which the lever presses), is the ground which the wheel touches. This, then, is the second order of levers, where the *fulcrum* is at *one* end, the *power* at the *other*, and the *weight between* them (Fig. 13).

But there is a third kind of lever. Have you ever noticed a man raising a ladder? how he places his foot on the lowest step to keep the bottom from slipping, and then he takes hold of one of the steps higher up, and by pulling this towards him he gradually causes the ladder to rise. In this case the fulcrum is the ground on which the ladder rests, the power is in the man's hands, and the weight is the

long end of the ladder; so here the **weight** is at **one end**, the **fulcrum** at the **other**, and the **power** *between* them; this kind of lever is shown in Fig. 14.

Now all three kinds of levers are met with in the human body. You remember that the skull rests on the vertebral column, which is the *fulcrum;* the head is drawn up and held in that position by the muscle at the back of the neck; this then is the *power*, and the front part of the skull is the **weight**; so that here we have the first order of levers, in which we have the weight at one end, the power at the other, and the *fulcrum* between them.

An instance of the second order of levers occurs in the foot. The ground under the ball of the great toe is the *fulcrum*, the tendon which draws up the heel (called the tendon Achilles) is the *power*, and the *weight* is the leg which supports the body; so you see that here we have the fulcrum at one end, the power at the other, and the *weight between them.*

The third order of levers is the one which occurs the most frequently in our body, and of this you have an example in the arm, in which the elbow-joint is the *fulcrum*, the fore-arm and hand are the weight, and the Biceps muscle is the *power* which is thus placed between the weight and the fulcrum.

The Teeth, and Digestion.

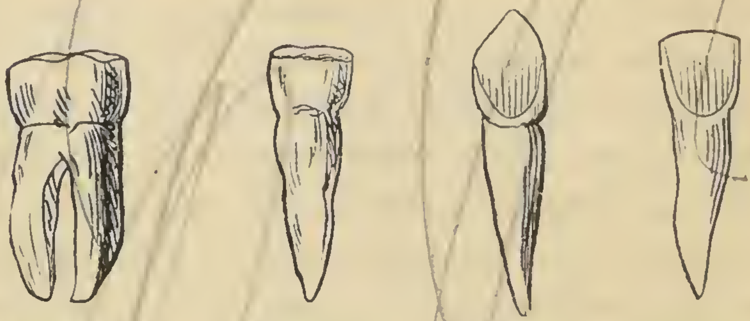
On page 14 you have been told that the motions in the jaws of animals are adapted to their mode of life and to the food on which they are to subsist, and that man, who can live on mixed food, animal and vegetable, possesses the power of moving the jaw in a manner which unites those of all the lower animals; not only is this so, but man's teeth are so formed as to enable him to "cut" or "grind" his food, assisted by the action of the jaw above alluded to.

A tooth is divided into three parts: the **Crown,** or upper portion; the **Neck,** or narrow part immediately at the bottom of the crown; and the **Fangs** or roots, by which it is attached to the socket.

The principal substance of which the teeth are formed is dentine, or ivory; this is covered beneath by cementum, a substance resembling bone; and above by enamel, a very hard crys-tal-line for-ma-tion, which consists of little six-sided blocks, called prisms, closely joined together. In the centre of the tooth is a soft matter called pulp, and a cavity into which blood-vessels and a nerve pass from a hole at the bottom. When any portion of the enamel has been chipped off in *cracking nuts or biting other hard substance*, the dentine wears away,

the nerve in time becomes exposed, and *toothache is the result.*

Human teeth are classed as follows :—



Molars. **Bicusps.** **Canine.** **Incisors.**

Fig. 15.

These are written of in what is called the Dental formula.

$$
\begin{array}{llllll}
 & \text{Left. Right.} & & & & \\
\textbf{Molars} & \left\{\begin{array}{l} 3—3 \text{ Upper Jaw.} \\ \overline{} \\ 3—3 \text{ Lower Jaw.} \end{array}\right. & \textbf{Bicusps} & \left\{\begin{array}{c} 2—2 \\ \overline{} \\ 2—2 \end{array}\right. & & \\
 & & & & \Bigg\} & \text{Total—32.} \\
\textbf{Canine} & \left\{\begin{array}{l} 1—1 \text{ Upper Jaw.} \\ \overline{} \\ 1—1 \text{ Lower Jaw.} \end{array}\right. & \textbf{Incisors} & \left\{\begin{array}{c} 4 \\ \overline{} \\ 4 \end{array}\right. & &
\end{array}
$$

These are shown in illustration 15.

Digestion.

In order that the waste which is constantly going on may be repaired, and that the body may increase in size, it is necessary that we should take food.

This food goes through various changes, until at last it is turned into a liquid which mixes with the

blood; and as the blood travels all through the body, the nour-ish-ment drawn from the food is carried into every part.

The process by which the food is turned into matter fit to mix with the blood is called Digestion.

The earliest form of digestion is seen in a little animal called **Amœba** (Fig. 16), which belongs to the group called **Protozoa**, or "first animals," as they are the first form of animal life.

Fig. 16.

And a wonderful creature indeed is this same Amœba. It consists simply of a little speck of a jelly-like substance, called *Sarcode*, from one three-hundredth to one six-hundredth of an inch in diameter, and is so strange in its form that one could scarcely believe it to be an animal at all. Here is a sketch of one, but you might never see one of this shape; nor would this remain so for an instant.

It has no mouth, nor even a head, yet it eats; it has no arms, and yet it seizes its prey; it has no

throat, but still it swallows; and it has no trace of a stomach, and yet it digests its food!

The mode in which this strange little animal eats, then, is this:—When, whilst swimming about in the water it meets with a minute grain of food, it sends out a foot, or leg, or arm, whichever you please to call it, draws it in and closes its body round it; for the sarcode, of which it is formed, is so elastic that it will take any form. The softer portion of the food is then retained, whilst anything hard in it is *pressed out from another part of the body.*

If you were to close a piece of dough around a ripe plum, and press it closely, the pulp or soft part of the fruit would get mixed with the paste, whilst the stone would be squeezed out from some part or other of the surface; and this will give you a good idea of the digestion of the Amœba.

In another little animal, called the **Fresh-water Hydra**, which is found hanging on to the under surface of duckweed, or to any small twig that may be floating in the water, we have at least a mouth and a stomach, but that is all. The little creature is simply a small tube, with long threads hanging from it, which can move about in every direction and seize its prey, which consists of small worms and other very tiny creatures. These it places in

its mouth, around which are the arms, it passes into the stomach, and any part which is not approved of is again *ejected from the mouth.* This animal was the subject of much study by a great naturalist named Trembley, who lived in Geneva, and who, in 1744, published a full account of it. From his observations it appears that the formation is so very simple that it may be turned inside out, just like the finger of a glove, and the whole process of digestion go on the same as ever.

Fig. 17.

From these, the lowest of all known creatures, up to man, every group of animals has a different system of taking and digesting its food, according to its mode of life. These are fully described in the book which forms a companion to this one, called "Animals; their Structure and Habits;"* and we can therefore confine our present studies to man alone.

* "Animals; their Structure and Habits." Uniform with this book, price 1s. Published by Cassell, Petter, and Galpin.

The first process to which the food is subjected on being placed in our mouth is **Mastication**, or chewing; and the description already given of our teeth will have shown you how these are adapted to the food we take. On referring to page 16, you will be reminded that our lower jaw moves horizontally, as well as up and down, and we are thus enabled to grind up the substances we are taking.

During mastication the mass is moved about by the tongue, and is moistened by a liquid called **Saliva**, which flows into the mouth from six glands, three of which are placed on each side in the following positions:—

The **Parotid**, inside the cheek near the ear.

The **Sub-maxillary**, under the lower jaw.

The **Sub-lingual**, under the tongue; this last forming the pink soft mass, divided by a sharp ridge, which you can feel immediately under the tongue.

The liquid poured from these glands (which are called the **Salivary Glands**), serves to effect certain changes in the food, and to moisten the mouth; and this process is called Insalivation.

The saliva flows into the mouth from numerous points, and in great quantities when food is placed there; but if we only touch the tongue with our finger the saliva will come; and this is why country people,

when walking along a road, put a small stone in their mouths, which, by causing the liquid to flow, prevents thirst.

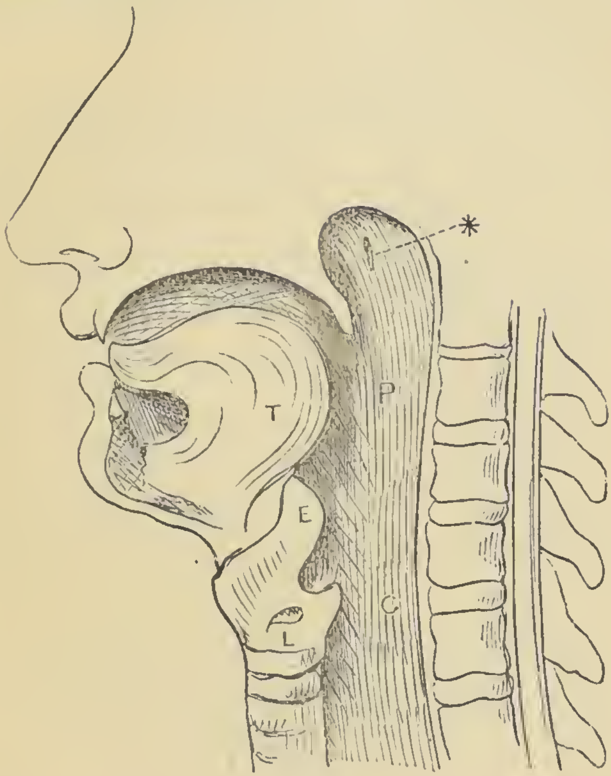


Fig. 18.

T. The Tongue.	E. The Epiglottis.
P. The Pharynx.	G. The Gullet.
L. The Larynx, or upper part of the windpipe.	* The opening of the Eustachian tube leading to the ear.

It also pours into the mouth even at the *thought* of food, and this is what is meant by "making the mouth water."

From the mouth, the food, having been masticated and mixed with saliva, is collected into balls at the back of the tongue, and then passes down into the throat, and thence into the lower end of the passage, which is called the **Gullet.**

But in its motion downward the food has to pass the windpipe, called the **Trachea,** the top of which, called the **Larynx,** opens into the throat; and, in order to prevent its falling in, the larynx is, in the act of swallowing, drawn under the base of the tongue, and is covered by a little flap called the **Epiglottis.** Sometimes, however, it happens that a morsel of food "goes the wrong way," that is, is drawn into the wrong opening, and then violent coughing follows, and by this means it is brought out again.

The positions of the various parts will be better understood on referring to the engraving (Fig. 18).

The food then, having passed through the lower part of the pharynx, comes to the gullet (G), and thence it proceeds to the stomach.

The **Stomach** (S) is simply a bag, broader at one (the upper) end than the other. The opening through which the food enters is called the **Cardiac orifice** (C). All over the interior coating of the stomach there are little cups, which give out a pecu-

liar fluid called **Gastric Juice** ; this juice is gathered in these little cells, and is poured from them into the stomach the moment any solid food enters.

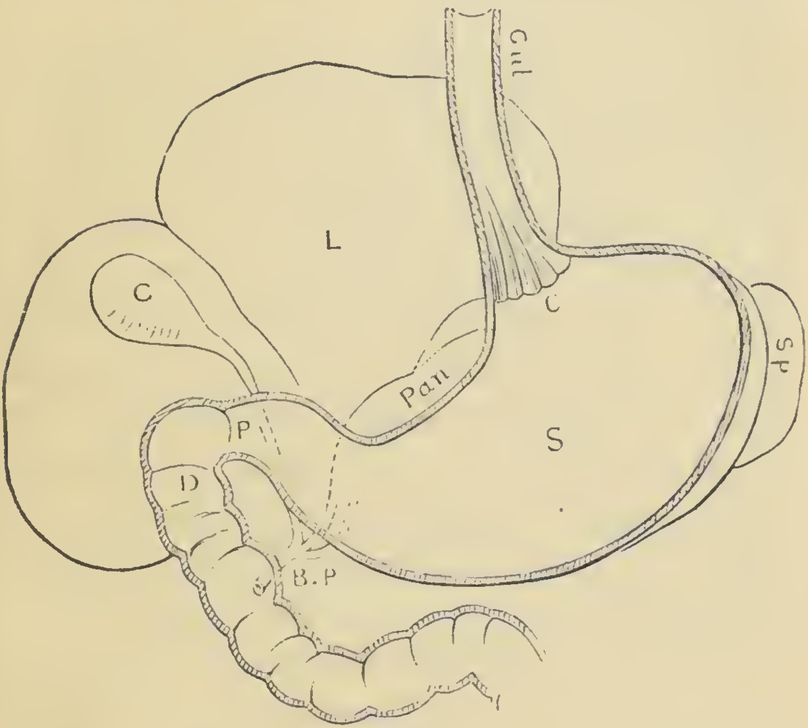


Fig. 19.

S. Stomach.
Gul. Gullet.
C. Cardiac Opening.
P. Pylorus.
Pan. Pancreas, or Sweet-bread.

L. Liver.
G. Gall Bladder.
D. Duodenum.
B P. Bile and Pancreatic Juice entering at same duct.
Sp. Spleen.

The whole stomach moves about during digestion, so as to bring the food in contact with its sides, in

order that the gastric juice may act on all of it. In this motion the upper part is raised, and so pushes up a membrane which covers it, which will be mentioned by-and-by.

The effect of the gastric juice is to dissolve the food in the stomach, and you can very well imagine that the length of time required for this purpose differs according to the substance to be acted upon. But as only a certain amount of the liquid enters the stomach, exactly the quantity required to digest the food which the system requires for its nourishment, it will be clear to you that taking too much food, or "bolting it" rapidly, must interfere with proper digestion; for where more food enters the stomach than can be dissolved by the gastric juice then present, the remaining portion has to remain undigested, causing pain and in-con-ve-ni-ence.

The food is prevented passing out of the stomach by the closing of the narrow end, called the Pylorus; this, however, opens from time to time, and thus allows as much as is dissolved to pass through.

The entire action of the stomach has been carefully observed in a very remarkable manner. Some years ago a young Canadian, named Alexis St. Martin, met with a very severe accident by the bursting of a gun, and the wound completely laid

open the side of the stomach. He recovered, but an opening remained, which would not heal; through this the process of digestion could be clearly seen, and some of the gastric juice was drawn out for the purpose of observing its effects on various substances.

These and other observations have now made it clear that of meats, venison seems the most digestible, that is, it takes the least time to dissolve; then turkey; next feathered game, such as pheasants, &c.; then chicken, mutton, beef, veal, and last of all, pork.

Vegetables take longer to digest than meat, and thus we find that in cows and other animals which live on grass and roots, the food canal is very much longer than it is in the lion and other animals which live entirely on flesh; this is to give greater time for the nourishment to be drawn out of the vegetables.

The food then is dissolved in the stomach and becomes a liquid, rather thicker than cream, which is called **Chyme.** This liquid, when it has passed out of the pylorus, enters the first portion of the small intestines called the **Du-o-de-num**, D, Fig. 19. Into this canal a small tube opens, made up of two others, one of which brings bile from the gall-bag,

G B, which has been gathered or formed in the **Liver**, L, and the other bringing pancreatic juice which has been formed in the **Pancreas**, P ; both of these juices mix with the chyme, and not only cause certain changes in it, but the bile assists in causing a peculiar motion of the bowels which is necessary for digestion.

From the inner coating also of the intestines another fluid, called the **Intestinal Juice**, flows, and mixes with the digested matter, and thus the *Chyme* is turned into **Chyle.**

This chyle then is called the "proceeds of digestion," because it contains all the nourishment which can be obtained from the food we have digested. And now another set of vessels come into play, the duty of which is to absorb or suck in all the juices thus formed, and to carry them forward so that they may be changed into new blood.

The first of these set of vessels are called **Lacteals.** These arise in the lining of the small intestines. They are very small tubes, and their walls are so very thin, that the fluid in the bowels, which is something like milk in appearance, passes through them into the lacteals and several glands belonging to them.

Now, you must understand that just in front

of the spine there is a tube or canal called the **Thoracic Duct.** This is widened into something like a bag at its lower end, and into this the lacteals pour the chyle.

Into this same pouch another set of absorbing vessels, called **Lymphatics**, bring a fluid called **Lymph**, which they have sucked in from the various parts of the body through which they have travelled, and then the mixture travels up the thoracic duct, and is poured into a large vein on the left side of the neck, and from there it flows direct to the heart. We shall, in the next chapter, see what becomes of the blood thus formed.

Before, however, we turn to a new branch of our subject, let us as briefly as possible look through what has been described concerning digestion.

In the first place, then, the food is masticated or chewed.

Secondly, it is mixed with saliva during mastication.

Thirdly, it is swallowed.

Fourthly, it is moved about in the stomach, and is mixed with gastric juice, and then becomes *Chyme.*

Fifthly, it passes out of the stomach into the small intestines, and is mixed, firstly with bile and pancreatic juice, and then with intestinal juice, and is then called *Chyle.*

Sixthly, the chyle is carried by *Lacteals* into the pouch of the thoracic duct; here it is mixed with lymph, brought by the lymphatics, and then passes up to the left side of the neck, where it is emptied into a large vein, which carries it direct to the heart.

The manner in which the absorbent vessels suck in the juices is very interesting, and I will explain it to you, so that you may in a very simple way observe the process for yourself.

Take a glass tube, and tie a piece of bladder, in the form of a small bag, at the end of it; pour some dissolved gum arabic into it, and then plunge the end into a cup or glass containing water. In a few moments the gum in the tube will begin to rise, and the water in the glass will sink, because the gum in the tube, being more dense than the water, draws it in through the bladder, and will continue to do so until they are equal. Again, if you put gum into the glass and water into the tube, the gum will suck in the water until they become the same thickness. This is called **Endos-**

mose, and it is on this principle that the absorbent vessels suck in the liquids which are thinner than what they previously contained.

Before closing this lesson on digestion, let me beg of you to remember how wonderful and how delicate is the whole structure by which it is carried on.

If you had a little model of a locomotive engine, or any other machine which you knew to be made of a many small parts, would you not be very careful of it? If you knew that it required an exact amount of a particular sort of fuel, would you not supply that fuel correctly, both as to quantity and quality? And if you knew that it could draw only a certain weight, would you risk breaking it by attaching a heavier burden to it?

And is not the living locomotive engine which I have described to you by far more valuable—by far more wonderful?

Let me urge you, therefore, not to take food which you are told is bad for digestion—such as the quantities of hard and unripe fruit, &c., which we so often see crammed into the pockets of boys, to be afterwards crammed into their stomachs—for this is giving the engine harder work to do than it is intended for. And even of healthy and proper

food do not partake in too great quantities. A moderate meal, well digested, will do more to nourish the system than a heavy one; for if too great a quantity of food be taken, it cannot move about freely in the stomach, to be acted upon by the gastric juice, and part of it must therefore remain there, causing suffering; or it may pass through the stomach undigested, clogging the intestines, and leading to illness of the most dangerous character.

More serious still is the want of moderation in what we drink. Spirits of every kind should be avoided, unless taken as a remedy; but if the system has become used to them, the cure will fail.

Spirits rush at once into the vessels which lead to the brain, and thus the intemperate man first becomes careless of what he says or does; soon, indeed, he loses all control over his words or actions; he staggers, he reels, he falls—falls indeed, from the position which should be held by the being created in the image of his God. He may recover from this state, but he is day by day losing strength, and losing also the regard of his fellow-creatures. He becomes unable to work, and but for the assistance of others would starve. Daily has the spirit destroyed the little ducts in the coating of the

stomach from which the gastric juice should flow; hourly has the liver been injured, and the vessels around it closed; and thus diseases have set in which death alone can end.

Let this warn you; and as the effect of the instruction you receive at school should be to strengthen you for your duties in after-life, so that you may resist bad habits when you have no longer the benefit of the guidance of your teachers, I hope that the lessons you have had on the use and abuse of food and drink may prove of service to you.

HOW OUR BODIES ARE NOURISHED.

The Blood and its Cir-cu-la-tion.

You have seen that the proceeds of digestion become blood, and that this fluid contains particles of all the substances required for building up the body and for repairing the waste which is constantly going on.

The object of this lesson is to show you how all this is done; but I must first tell you that the blood is not entirely liquid, but has solid particles in it; these, in man, are round, like pieces of money, only that they are not quite flat, but have

a spot in the middle which is slightly pressed in. These small bodies are called "**Blood Corpuscles,**" and some of them are colourless, but most of them are red; and these contain a certain quantity of iron.

You will be able to examine these for yourself by means of a microscope, but you must not be surprised at not seeing the red spot very plainly, as it is so small that it is scarcely visible unless when a great many of the corpuscles are together; and when I tell you that they are only about $\frac{1}{3500}$ *part of an inch* in diameter—that is, three thousand five hundred of them placed in a line would only measure one inch—and that they pass through little tubes which are called "capillaries"—which means "hair-like," but which in reality are much finer than the finest hairs—you will be able to form some idea of their extreme smallness.

Now I must tell you that in its course through the body the blood has three duties to perform:—

First, as you have already seen, it has to convey nourishing particles to every part.

Secondly, it has to carry not only nourishment, but a sort of gas called oxygen. This gas is necessary for all animal life: the blood fetches it from the lungs, as you will see presently, and takes it over the entire system.

Thirdly, the blood has to bring back all used-up matter, and also another gas called "Carbonic Acid," which has been formed in the body, but which destroys animal life; it is therefore carried along by the stream of blood, in order that it may be expelled from the system.

And now we must turn our attention to the heart, which is the engine by which all this wonderful motion is accomplished.

The heart is a muscular bag, formed of two distinct portions, which are separated by a wall, and each of these portions is again divided into two; and there are thus *four* chambers, the position of which you will understand from the annexed drawing, which represents a heart cut through, so as to show you the inside.

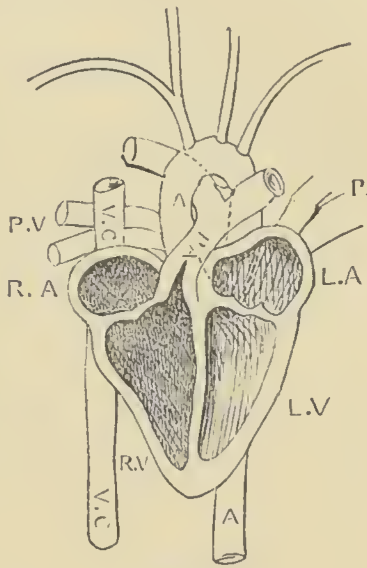


Fig. 20.

V. C.—Vena Cava.
R. A.—Right Auricle.
L. A.—Left Auricle.
R. V.—Right Ventricle.
L. V.—Left Ventricle.
P. A.—Pulmonary Arteries.
P. V.—Pulmonary Veins.
A.—Aorta.

The two upper chambers are called **Auricles**, and the two lower ones are termed **Ventricles**: thus we have the Right Auricle and the Left Auricle, the Right Ventricle and the Left Ventricle.

Two liquids then come to the heart:—First, the old blood, which has travelled all through the system; and, second, the matter formed of our food which is to supply new blood.

The blood from the different parts of the body below the chest is brought by a countless number of veins, which unite into one large canal, called the **Inferior** (or lower) **Vena Cava**; that from the head and neck is brought by the **Jugular** veins, which meet the **Subclavian** veins, bringing the blood from the arms.

At the point where these two veins meet, and form the **Superior** (or upper) **Vena Cava**, the proceeds of digestion are poured in from the thoracic duct, and are thus carried with the blood to the heart.

The upper and lower vena cavæ enter the right auricle, and the mixed liquid which they bring passes thence into the right ventricle.

But you will remember that the old blood has to get rid of the carbonic acid gas which it has gathered in its course, and that when the new

stream starts again it must take with it a supply of oxygen.

For this purpose it is now propelled (pushed forward) into the **Pulmonary Arteries,** which carry it to the lungs. How the lungs act upon the blood I will explain to you in the next lesson; it will be sufficient at this moment to tell you that the required change *is* effected in the lungs, and that the blood returns by means of the pulmonary veins, which pour it into the **Left Auricle.**

And now the colour of it is changed; for whilst in the veins it was of a dark colour, it has, by the action of the air in the lungs, become a fine *bright red,* and now it is the pure blood which is to nourish the body.

From the left auricle the blood passes into the **Left Ventricle,** and out of this last chamber a large canal proceeds, called the **Aorta.** The tubes which convey the blood are now no longer called veins, but **Arteries,** and it may be well to impress on you in this place the exact distinction between these—namely, that **Arteries convey the pure blood from the heart** to nourish the body, and were so called because it was formerly thought that they contained air, which is now known to be untrue; the **Veins bring back the old blood** to be rid

of its carbon, and to receive oxygen and new matter.

The **Aorta is the largest of the Arteries.** From the left ventricle of the heart it proceeds upwards, and then bends in the form of an arch; from this part it sends out branches called Subclavian Arteries, which carry blood to the arms, and the Carotid Arterics, which supply the head and brain. The Aorta then travels downwards, and towards the bottom of the trunk it divides, and sends a large branch into each leg and foot, numerous branches proceeding from each.

The arteries gradually become smaller and smaller, until they become capillaries; these again gradually increase in size, and become veins, and it is in this way that the arterial blood which has travelled throughout the body is returned to the heart.

From the engraving (Fig. 20) you will see that the wall of the left ventricle is thicker than any other part of the heart; this is to give it the great muscular power which it requires to force the blood into the remote extremities of the body.

The course of the blood throughout the entire system is called the **Greater Circulation**, and its passage through the lungs is called the **Lesser Circulation.**

There is, however, a third system, by which the blood passes through the Liver, and this is called the **Portal circulation.** You must understand, then, that the *veins* which are bringing back blood from the intestines, stomach, and spleen, *do not enter the vena cava*, but they all unite and form a large vein called the **Vena Porta**; this enters the *Liver*, divides into an endless number of capillaries, and travels through the entire substance, and from this blood, as it travels through the liver, the bile is formed, which is afterwards conveyed by the gall-duct into the *Duodenum.* (*See* page 51, and Fig. 19.)

These capillaries again unite and form the **Hepatic** vein, which carries it into the *Vena Cava.*

The blood which came from the digestive organs has now, in its passage through the heart, not only supplied the bile, but has become changed and purified in other ways, so as to fit it for being mixed with the proceeds of digestion, and with the blood coming from the other parts of the body.

I will now explain to you the movements of the heart, in order that you may understand how this wonderful action, to which we owe our life, is carried on. The moment the right auricle is filled it contracts, and forces the blood into the right ventricle, which, on being thus filled, contracts also, and drives the blood into the pulmonary arteries.

And here I must pause to tell you that, whilst the auricle contracts, the blood *can* only pass one way—it cannot be pressed back again into the vena cavæ, because the mouths of these vessels close the moment they have sent a full jet to the heart; and again, whilst the ventricle contracts, the blood *must* go forward, for a valve in the partition closes, and thus prevents it returning to the auricle.

In the pulmonary artery, as you know, the blood is carried to the lungs; and here again any return is prevented by the closing of valves called the semi-lunar, or "half-moon-like."

Whilst this is going on in the right, a similar action is proceeding in the left side of the heart. The blood returns from the lungs by the pulmonary veins, and fills the left auricle, which then contracts and fills the ventricle. Then comes the strongest contraction of all, by which the blood is forced into the aorta, and thence over the entire body.

If you put your ear against the chest of another person, you will hear two sounds: the first, dull and rather long; the other, sharp and short. Then a pause, and then the sounds again. The first sound is caused by the contraction of the walls of the ventricles, and the second by the closing of the semi-lunar valves, which I have already mentioned. The movement of the pulse in the wrist

follows immediately after the first sound, and at the same time the heart is forced against the walls of the chest, and this is what is called the "beating" of the heart.

The circulation of the blood was discovered by Dr. Harvey between 1619 and 1628.

How our Blood is Purified in the Lungs.

In the last lesson you have seen that the blood is carried by the pulmonary artery to the lungs, and we will now consider the means by which it is there purified.

You must first, then, understand that when air has entered our mouth it passes down the **Trachea**, or windpipe, which, you will remember is the lower part of the larynx. This canal passes down into the chest, and then divides into two large branches, called **Bronchial Tubes** (*see* Fig. 21), one of which passes into each lung, and there they divide again and again into numerous smaller branches, which spread about in every direction.

These tubes are very wonderful in their structure, and afford only another specimen of the wisdom and mercy of our Divine Creator.

In order to guard against their being pressed flat by the continual action of the chest, rings or plates, formed of cartilage, are placed in them,

which serve to keep them open. A similar arrangement, on an infinitely smaller scale, exists in the tubes which carry air over the body of the tiniest insect.

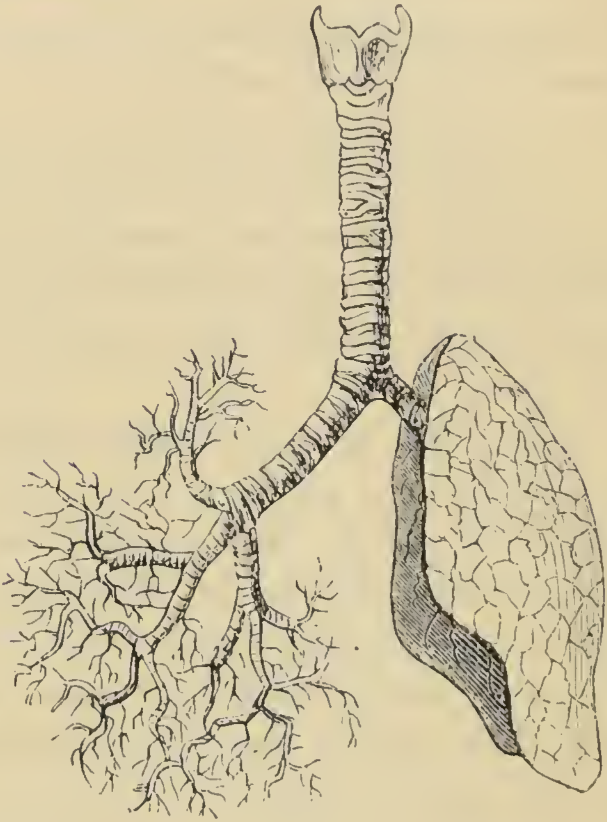


Fig. 21.

The Larynx, Trachea, and Lung. (One lung is removed to show the bronchial tubes.)

When the bronchial tubes have spread about like the branches and twigs of trees, they end in a number of small bags, called **Air-cells**, all of which open into the tube from which they spring; and

when the air passes down into them, they dilate or spread out, just like a bladder or paper bag does when you blow into it. Thus you will see how the air is supplied to the lungs; and now let us see how it acts on the blood.

The pulmonary arteries, which bring the blood in its impure state from the right ventricle of the heart, when they have entered the lungs, divide and subdivide into the most minute capillaries, which spread like the finest network over the little pouches or air-bags which you have seen are at the end of the bronchial tubes; and the walls both of the capillaries and of the pouches are so very thin, that the air can pass from one to the other; and the air which passes from the bronchial tubes into the capillaries contains a sort of gas* or spirit called Oxygen gas, another called Nitrogen, a very little Carbonic gas, and some watery vapour. The oxygen is, however, the gas which is absolutely necessary for the preservation of animal life, and therefore I will speak of it only, the principal use of the nitrogen being to dilute or mix with the oxygen.

But not only does oxygen pass into the capillaries, but carbonic acid gas, which is most injurious to us, passes out of them. The capil-

* The word "gas" is supposed to be derived from the German word *Geist*—spirit.

laries then change their character. They are no longer, as it were, small drain-pipes filled with poisonous matter, but their contents have been changed; the impure portion has passed away, and has been replaced by that which is pure. And now they gradually expand into larger channels, and, uniting into the pulmonary veins, carry the vital fluid, the stream of life, back to the heart, to travel thence over the entire system.

I must now explain to you the action by which the air enters into and is forced out of the lungs. You will remember that in the lesson on the bones of the trunk, I told you that the ribs, although attached at the back to the bones of the spinal column, are not fixed in a rigid or immovable manner, but by means of a joint; and further that the bones of the ribs are not carried quite round to the breast-bone in the front, but are joined to it or to each other by cartilage, an arrangement which permits of the thorax or chest being

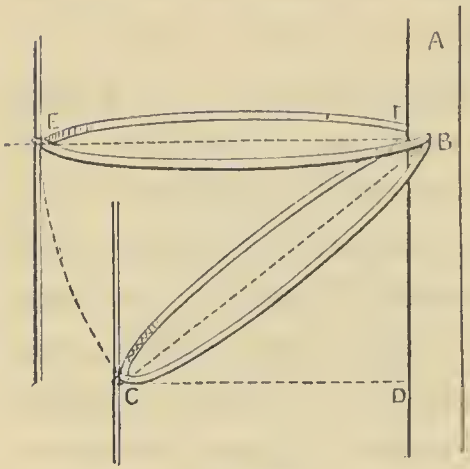


Fig. 22.

increased in size in a most simple manner. This sketch will teach you how to make a little model for yourself, by which you will at once understand how additional space is obtained for **Respiration,** which is the name applied to the act of breathing.

Take a piece of wood, A, and bore a hole in it at B; through this pass a cane, and then tie it into the form of a hoop.

Now tie another flat piece of wood to the part of the hoop opposite to A, then, if the hoop is allowed to hang down, the line C D will be the width of the space between the front and the back of the hoop; but if the front of the hoop is raised to D E, the cavity will be increased to E F. That space is thus gained you will see at once, for even in this small drawing C D is one inch, whilst E F is an inch and a quarter.

Now this is one of the ways in which the size of the thorax is enlarged.

By means of muscles the front of the ribs is drawn up, and the breast-bone forced outward, its distance from the spinal column is thus increased, as you have seen in your model, whilst at the same time other muscles tend to widen the chest from side to side.

But I have only up to this spoken of the *walls* of the thorax, and must now tell you that the floor

of the cavity is formed by a broad muscle called the **Dia-phragm** (pronounced *di-a-fram*), which separates the stomach, liver, and intestines from the lungs and heart, dividing the interior of the trunk into two chambers, the upper one of which is called the **Thorax** and the lower one the **Ab-do-men.**

Now, when in repose—that is, at the moment when we have breathed—the diaphragm forms an arch or dome, but at the moment of drawing in air it contracts, thus making the floor of the chest *flat* instead of *round.* Of course the chamber is thus enlarged, and as in nature no space is ever allowed to remain empty, the air rushes in and fills the lungs, which then expand. This is called **Inspiration.**

The muscles then relax, the front part of the entire framework drops, and the air, changed in character and bringing with it the carbonic acid gas, is pressed out of the lungs; this is called **Expiration.**

The whole of the air is not, however, expelled; a certain quantity remains in the air-cells; this is called **residual air,** and it is this which gives up its oxygen to, and receives the carbonic acid from, the capillaries.

The residual air does not remain after this in the

air-cells, but mixes with the next current and is expelled, its place being taken by a fresh supply.

As the diaphragm falls it presses on the stomach and other organs which recede before it, **but if the stomach be full it does not allow the diaphragm to descend**; the increase of the thorax is thus prevented, and, of course, the proper quantity of air cannot be inhaled.

This is the reason why many who have taken too heavy a meal find difficulty in breathing afterwards, and I must warn you against this, for you know that the blood is continually flowing to the lungs to be purified, and if there is not a proper supply of air in them of course they cannot perform the office for which they are intended, and the blood passes on without its carbonic acid gas being taken from it or oxygen having been imparted to it.

For the same reason we should be careful to avoid damp clothing or other means of taking cold, for when the bronchial tubes become inflamed or obstructed the malady called bronchitis ensues, which, unless promptly and properly attended to, may become most dangerous in its consequences.

The lungs are wrapped in a very delicate membrane called the **Pleura**; this is double, and by means of a liquid (serum) between its surfaces, it enables the lungs to move freely; this membrane

too is liable to inflammation (pleurisy) from damp or cold.

But do not think that because you are warned against the ill effects of taking cold that you are to be constantly wrapped up, or to keep all the doors and windows of your rooms closed; quite the contrary. **Pure fresh air is as necessary for your health as food or drink**; and you must remember, that when there are several people who are all sucking in the good air or oxygen, and are breathing out carbonic acid, the room will soon become filled with this poisonous gas, and, unless a fresh supply of oxygen be admitted, the same air which has come from the lungs is drawn into them again, and you can thus clearly see that *this* would not serve to purify the blood. This it is which makes you feel so tired and dull after sitting for a long time in a crowded room, and which causes fainting in so many persons. A fearful instance of the results of shutting out air took place in Calcutta in 1756, when 146 British prisoners were crammed into the Black Hole prison, an apartment eighteen feet square, and only *twenty-three came out alive next morning*. Let me urge you then to make plentiful use of the beautiful fresh air so bountifully given to you; but you must understand the *principle* on which you should use it in your rooms, or you will not receive the full benefit from it.

Carbonic acid gas, which is the air you would obtain by burning charcoal, although heavier than other gases, does not in a room fall to the ground until it has become the greater part of the atmosphere; it gathers up next the ceiling; now it is not enough, therefore, just to open a window, for this would only blow it to the distant part of the room, or pack it closer against the ceiling.

Openings should therefore be made in the cornices round the top of the room, or in the wall, to allow it to escape, and then a door or window open lower down will assist in pushing the bad air out and will take its place.

You will, perhaps, wish to know what becomes of all the carbonic acid gas which is breathed out by the immense numbers of persons in large towns, and of that which comes from all the coals and gas burnt?

It is all used; and for what purpose do you think? why **it is food for plants**, and every leaf of the trees, every blade of grass, opens numberless mouths to suck it in, and so assists to purify the air which might otherwise become unbearable, at the same time that vegetable products in thousands of different shapes are being formed for us.

I have already mentioned the larynx or upper portion of the windpipe, and an opening in it

called the glottis ; across this the **Vocal Cords**, two in number, are stretched, and when the air from the lungs rushes in between these, the sounds which we call the *voice* are produced ; the different tones and sounds (called the pitch) being formed according to the degree in which the vocal cords are relaxed or tightened by the muscles acting on them. These sounds are further altered by the agency of the tongue, teeth, palate, and lips, so as to produce the sounds which we call speech.

Sighing is nothing more than a very long-drawn breath ; it occurs when some sorrow or anxiety causes us for an instant to "hold our breath ;" in fact, we do this sometimes when our attention is fixed on any particular matter, then follows a longer or stronger expiration of air.

Yawning is a still deeper inspiration, but is not entirely voluntary, as a sort of spasm of some of the muscles, principally caused by fatigue, occurs. There is however, a certain tendency to imitation in this, for we often yawn just because we see others do so.

Sobbing is caused by a convulsive movement of the diaphragm, and a closing of the glottis ; whilst hiccup is occasioned by the sudden closing of the glottis when a current of air is moving past it.

Laughing is caused by the breath being sent out

in *jerks*, the glottis being open. This sometimes goes on until the lungs become more emptied of air than they would be under usual circumstances, and thus we hear people say "they laughed until they were out of breath."

Crying, though arising generally from the opposite feeling to that which induces laughter, is caused by very nearly the same action of the breath; in fact, sometimes there is doubt whether the act is laughing or crying, for the one may merge into the other.

Coughing is the result of some irritation, generally caused by cold, acrid smells, or some foreign substance impeding the passage of air in the throat or bronchial tubes; whilst sneezing is a similar obstruction or irritation in the tubes passing through the nose.

The organs of digestion, circulation, and respiration having been thus fully described to you, you cannot fail to see how perfectly elastic is the whole structure by which they are contained.

Nature has thus shown us that these organs require perfect freedom in order to act healthily, and this warns us against the folly, nay, the absolute wickedness, of confining our bodies by tight belts, stays, or other rigidly-fitting clothing; it is folly because we are inflicting pain and suffering on our-

selves; but, more important still, it is wickedness because we are hindering the organs which have mercifully been designed for our health and benefit from performing the functions for which they have been intended.

These considerations must be particularly noted by young people and children, for in youth the bones, in consequence of their containing a greater proportion of gelatine than remains in them later in life, are more flexible than they are in grown-up people, and, by being tightly laced or strapped up day by day, become bent inward, and *grow so.* Thus the cavity of the chest becomes smaller than it would have been; the lungs and other vital organs are impeded in their action, and permanent maladies are brought on; and thus misery and suffering is laid up for old age, if, indeed, old age be reached at all.

Nor are tight-lacing amongst girls, and the strap around the waist of boys, the only evils, though both of these may be avoided; there still remains something which is more difficult to overcome than either—namely, a *bad habit.* This requires not merely strength of body, but strength of *mind,* to overcome; and the habit here alluded to is "stooping."

You have been shown that, in breathing, the

muscles have to be drawn up so as to expand the thorax; and you have seen that upon the proper enlargement of the thorax depends the proper filling of the lungs with air, and the purifying of the blood; and as the blood nourishes the whole system, the well-being of the entire body depends on it, hence it is called the "vital fluid," the stream of life; and you cannot fail to see that, if the body is bent forward, the ribs *cannot* rise, the lungs *cannot* be inflated, the blood *cannot* be purified, and the system *cannot* be properly nourished.

You may think that you only stoop *now*, and will *grow out of it.* Now depend upon it this is a mistake. *Any* habit constantly indulged in becomes "*second nature,*" and in this case particularly so; for the cushions placed between the vertebræ (refer to page 18), being constantly pressed in a forward direction, become thinner in front, the bones thus bend forward, and permanent stooping and injury to the lungs is the consequence.

And all this time you are betraying a trust which God has reposed in you.

He has entrusted you with a glorious possession—the mansion in which the spirit is to dwell on earth—and you are neglecting it, nay, injuring it, instead of doing your best to strengthen it, as you would if a *human* master had permitted you to live in one

of his houses ; and further, you are neglecting your highest duties to your family and to society.

It is the bounden duty of every one to preserve his health by every means in his power. Think of the suffering, the anxiety, and the expense caused to those around us when we are sick. This too often happens when we *cannot* help it. But do not think you alone are the sufferers when you have defied the laws of nature. Those you love, and who love you, or your countrymen who must bear the expense of those, who by illness, are unable to support themselves, must all be considered ; and it is therefore your duty to preserve your health so as to become a useful member of society, instead of becoming a misery to yourself and a burden to those around you.

The Brain and Nervous System.

The brain is that great mass of matter contained in the skull, which is the centre of all thought, feeling, and action ; it is, as it were, the great central office from which instructions proceed by which a whole system is worked, and at which intelligence is received of all that is done in the most distant parts. The brain may, in fact, be considered as the centre of a telegraphic net-work, the wires of which are the nerves which are so closely woven over the entire body.

The brain is wrapped in three membranes :—

1. The **Dura Mater** is that which is outermost, forming as it were a lining to the skull.

2. The **Arachnoid** is the serous membrane which envelopes the brain, in the same way that the pleura covers the lungs, and being reflected or doubled, with a liquid between its surfaces, the brain is enabled to move smoothly.

3. The membrane immediately touching the brain, called the **Pia Mater**, which is made up almost entirely of blood-vessels, by means of which blood is conveyed from the carotid artery to nourish the entire substance of the brain.

This important organ consists of the front and upper portion, called the **Cerebrum**, which is by far the larger portion, and the **Cerebellum**, or little brain, which forms the lower part of the back of the brain. The Cerebrum is divided into two portions by a deep partition from front to back, but the two lobes are joined at the bottom, form a long stalk-like mass, which is continued down the canal in the vertebræ, and is called the **Spinal Cord**, of which we shall speak presently.

The Nerves are delicate cords or threads, made up of grey matter, which seems to be the actual nerve substance, and is called the **Axis Cylinder** (*see* Fig. 23); outside this is a covering of white

matter, called the "**White Matter of Schwann**" (the discoverer), and outside this is a very delicate membrane called the **Neurilemma.**

Fig. 23.

Nerve Fibre cut through, and highly magnified.

The purpose of the white matter which was discovered by Schwann is to prevent the nerve force which is passing along any one nerve to be communicated to, or interfered with by, the other nerves which touch it; it is, in fact, a non-conducting material, and is used as we use the coating of gutta percha with which we surround our telegraphic cables; and around this white matter the neurilemma serves as a covering.

The nerves which spring from the brain are called **Cranial**, because they arise within the cranium or skull, and those which arise from the spinal cord are called the **Spinal** nerves.

The Cranial nerves consist of **nine pairs** :—

1. Those which are distributed over the lining membrane of the nose, and thus form the seat of the organ of smell.

2. The Optic nerves, which give us the power of sight.

3, 4, and 6. Nerves distributed to the muscles

which move the eye, giving the power of moving the organ to any point, above, below, or sideways.

5. The nerves of the face and tongue.

7. Nerves distributed to the face and ear.

8. Nerves which spread over the tongue and throat, the lungs, larynx, and stomach, and which give motion to muscles at the back of the neck.

9. The Nerves which act on the tongue.

The Spinal nerves possess two sets of roots, one of which proceeds from the front and the other from the back of the spinal cord, Fig. 24; these are called the Anterior, A, and Posterior, B, roots; both these roots soon unite and form the trunk of the nerve. It was discovered by Sir Charles Bell* that the posterior roots consist of those fibres which bring *impressions from* the body in general to the spinal cord, and thence to the brain itself, when they become *sensations.* On the other hand the anterior roots consist of fibres, which convey motor influence, that is, *instructions to move from* the brain to the *muscles* of the body.

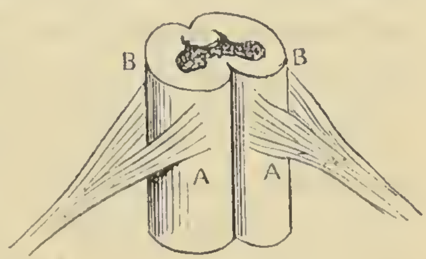


Fig. 24.

* Born in 1744; died in 1842.

Thus, when you put your hand on a book, the nerves of touch carry the sensation to the spinal cord, entering by the *posterior* root, and then you perceive that you *have touched* it; but if the mind desires that you should *lift* the book, the *motor* fibres coming from the *anterior* roots carry the instructions to the muscles of the arm and hand, and the order is instantly obeyed; and this takes place instantaneously, so that our acts really take place at the moment that the idea from which they originate leaves the brain; and, further, several sets of nerves may be acting together, each one doing its own duty to perfection, and with a rapidity which you would scarcely believe.

The following result of my own observation will convince you of this:—A lady has played for me a piece of music, which contains 1,890 separate notes, in *four* minutes; now, as she did not know the piece by heart, she had of course to look at the music, and thus the impression of the note, its position on the stave which gives its name, the number of dashes attached to its stem which give its duration of time, as a crotchet, quaver, &c.; its character as piano or forte (soft or strong), had to be conveyed to the brain by the nerve of the eye; instantly the message is sent by another nerve to the fingers, instructing them

which note to strike—not merely *any* key, but one to correspond with the note on the paper; and as each note occurs on the key-board of a piano once in every eight, it is necessary that the *particular one* intended, should be touched, and that it should be touched softly or firmly as directed. But this is not all; the attention of the mind must be divided, for a portion of the piece of music (the bass) has to be played with the left hand, and these keys have to be struck at the same moment with the others; so that all these perceptions have to be sorted out in the mind, and instructions sent out accordingly, and all this 1,890 times in four minutes, or at the rate of 472 notes per minute!

But the nerves of the ear are at work also, and if a wrong note be played it is at once perceived; and, at the same time, other portions of the brain are engaged in counting, so that the music may be played in right time.

The spinal nerves are arranged in thirty-one pairs, which are classified according to their position as follows:—

8	pairs of	Cervical (in the neck).
12	,,	Dorsal (in the back).
5	,,	Lumbral (in the loins).
6	,,	Sacral (near the sacrum).

Having thus described the general arrangement

of the nervous system, I will devote the following lessons to the special sets of nerves, the action of which produce those powers called the senses.

The Senses.

By the senses we mean those groups of nerves which convey special sensations to the brain.

Thus, by the sense of *touch* the mind is informed of the form and other qualities of matter, without any aid from the eyes.

We can perceive, by merely passing our hand over any object, whether it is flat or round, rough or smooth, warm or cold; and this same sense of touch is so distributed over the whole body, that we can form ideas of all the above qualities, if we touch the object with our leg, our arm, or our fingers; but more accurate and refined power of touch exists in some parts (as in the points of the fingers) than in others.

In this general distribution, the power of touch differs from the other senses, which are purely local. Thus, the sense of sight is placed in the eyes; that of smell, in the nose; that of hearing, in the ears; and that of taste, in the tongue. But there is a certain *association* of ideas brought about by the action of these special senses. For instance, if we close our eyes,

and two files are rubbed together, we *hear* their sharp, grating sound, and we can tell, without *looking at them*, that the surfaces are *rough;* and even without submitting them to examination by the eyes, we could tell, on touching two *smooth* pieces of metal with our fingers, that these were *not* the pieces which made the noise; and, further, the moment we look at the polished surface of a looking-glass, we can tell that it will be *smooth* to the touch. Still, this connection is, to a certain extent, the result of our previous knowledge of the relative qualities of bodies—namely, that we are *accustomed* to think of a file as rough—in fact, most of us know that it *is* so, and, therefore, when we hear the grating noise, we at once associate it with rough bodies, because we *know* that two smooth pieces of wood or metal would glide noiselessly over each other.

The senses can all be strengthened by cultivation—this is owing, possibly, to the nerves being strengthened by use, as muscles are. Thus, I have had deaf pupils in classes, whose power of sight and observation have become so strongly developed, that they have followed the most difficult geometrical constructions which have been worked on the black board, and have taken such accurate notice of the relation of one line or form

to another, that they have been able to answer written examination questions on the subject.*

It is a well-known fact, too, that blind people can hear better than others—evidently from their having found the necessity of listening carefully, in order to make up in some degree for their deficiency of sight. In fact, to such an extent have the results of the benevolent efforts to instruct the blind been successful, that not only are they able to form correct notions of form, so as to make numerous useful articles, but some can even distinguish between colours.

We will now consider the special organs of the senses in the following order:—1. Touch; 2. Taste; 3. Smell; 4. Hearing; 5. Sight.

The Sense of Touch.

The sense of touch, although more perfect in some parts than in others, is in reality spread over the entire surface of the skin.

The skin is a membrane of the utmost importance, as it has duties other than that of touch to perform, for it forms a widely-spread surface for evaporating (that is, carrying off in vapour) a great portion of the moisture which has passed

* A student of one of my classes, who is totally deaf, obtained a prize in the 1868 Science Examination of the Government Department of Science and Art.

through its changes in the system, and is no longer wanted, and also for getting rid of other waste-products which it is necessary to throw off.

This wonderfully constructed membrane is very strong, but at the same time elastic, particularly over the joints; and in the lower portion of its thickness is supplied by numerous blood-vessels and nerves, which are so closely interwoven, that it is next to impossible to prick the skin at any part, even with the point of a needle, without giving pain, and drawing blood; but to do this, the needle must pass through the upper skin, and touch the lower, for you must know that the skin consists of two layers—the outer one has neither blood-vessels nor nerves, and is called the **Cuticle**, or scarf-skin; and the lower one, called the **Cutis**, or true skin, in which the numerous blood-vessels and nerves already mentioned are found. These render it so highly sensitive, that were it not covered by the scarf-skin, we could not endure life. It is the cuticle or scarf-skin which is raised into a blister by burns, or otherwise, and no doubt many of you will know how very painful and tender is the pink skin which is exposed when the blister has been opened. This tender red membrane is the cutis or true skin.

The upper surface of the cutis rises into little

ridges called papillæ, and into these the capillaries and nerves rise. The scarf-skin, which is sometimes called the epidermis, has depressions or cavities, into which the papillæ fit, and so the tender nerves are protected by the scarf-skin, which in itself has no feeling.

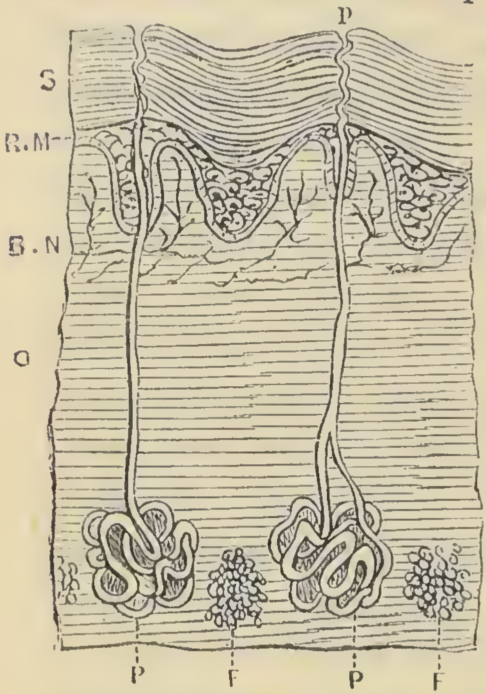


Fig. 25.

Edge of a cutting of a piece of Human Skin.

S. Scarf Skin.
C. Cutis.
P. Perspiratory Glands and Ducts.
F. Fat Granules.
R M. Rete Mucosum.
B N. Blood-vessels and Nerves in Papillæ.

You will understand all this better by referring to the annexed engraving, which represents the edge of a cutting of a piece of human skin, magnified 130 times.

Here the **Cutis** or true skin is marked C, and the **Scarf-skin** S, and the papillæ, or ridges, are marked p. The scarf-skin is formed of different layers, composed of numerous cells (or little bags) in its deeper portion. These cells are globular in shape, but as they come near the surface they gradually

become flatter—become so many scales, which are, in reality, portions of the waste which is to be thrown off, and these are removed by washing and proper rubbing.

When these flattened cells are pressed together, they become flatter and flatter, and thus the hard, horny skin is formed, which is seen in the hands of those engaged in hard manual work; and it is the pressure of tight-fitting boots which causes the hard ex-cres-cen-ces on the joints of the toes, called corns.

The deeper portion of the cuticle is called the **Rete Mucosum**, or mucous network. It is in this portion of the skin that the colouring-matter is contained; this consists of minute specks of colour, placed in little cells. In the fairer races of mankind these tiny specks are of a pinkish colour, but in negroes they are darker, and more closely placed, and this causes the black and swarthy colour of the skin. There is no doubt that the heat of the sun serves to darken these colour-cells, as the negro's face and backs of the hands are darker than the parts which are less exposed; but the colour is entirely confined to this part of the skin, for the cutis of the negro is of the same colour as that of other people.

The Sweat or **Perspiratory Glands** consist of lengths of very fine tubing coiled up into balls, from each of which a canal called the *perspiratory*

duct travels to the surface of the skin. All over this little ball of tubing the capillary blood-vessels spread their net-work, and from these the cells with which the tubing is lined draw out the water which comes to the surface in the form of perspiration.

The secretion and discharge of sweat is constantly going on, though we do not notice it when it is merely proceeding in its usual manner; but in hot weather, or when we have had violent exercise, it is much increased, and collects in the skin in drops, which form a stream and run down.

This forced perspiration, however, draws from the blood moisture at a rate faster than the blood is prepared to part with it in the natural course of things; and thus, after a copious perspiration, we feel weak for a time. You must be careful after running, or otherwise throwing yourself into a strong perspiration, not to expose yourself to sudden draughts or cold. Thus, if you are going to swim in the river or to take a cold bath, you should not do so until you have allowed the perspiration into which you may have fallen by running to end gradually; for, if suddenly checked by plunging into the cold water, the effects might be very injurious to you.

Nor should you confine the perspiration by too heavy clothing, for you know that the water

has to evaporate, so as to allow other to come out, and if the ducts are kept full of perspiration which ought to have passed away, of course they cannot do their duty. Again, perspiring goes on at night as well as by day, and as we have not then the healthy exercise as in the daytime to throw it off, we should not indulge in too warm night-clothes, nor use too heavy covering. Persons who do so, and constantly find themselves in a perspiration on awakening, arise from their beds not refreshed by their rest as they ought to do, but weakened by the excessive drain upon the system which has taken place.

You will be able to a certain degree to understand *how* closely the perspiratory ducts exist, when you are told there is an average of 2,800 of them on every square inch of surface over the body, and that in the palm of the hand there are about 3,500 to each square inch.

In order to promote and keep up the healthy action of the skin, it must be constantly cleansed by washing and rubbing; for if the perspiration dries on the surface, the mouths of the ducts, or, as they are called, the *pores* of the skin, become stopped up, and of course the proper flow of sweat is prevented.

Simple bathing is not enough, for the dried

perspiration mixes with a certain amount of greasy matter on the skin; and for this reason we use soap, which mixes with this, then an *alkali* (soda) contained in the soap serves to cause the greasy matter to unite with the water, and so both are removed together.

The **Nails** are only portions of the cuticle in a hardened form. They serve, by their horny texture, to protect the delicate nerves in the outer portion of the ends of the fingers and toes from injury, and afford a support for the soft extremities.

The human nail differs wonderfully from the same structure in other animals, being broad, nearly transparent, and flat, instead of narrow and claw-like. It grows from a sort of groove, something like that in which a watch-glass is fitted. The nail grows not only from its lower part, but from small roots, spread over the entire surface which it covers. This growing is increased by constant cutting. Still, the nails should not be allowed to grow long, for when their edge projects too far, it interferes with the extreme point of the fingers being used, and is a hindrance in writing, drawing, &c.; and further, unless great care be taken, the neat and cleanly appearance of the fingers is destroyed.

Hair.—Hair is a delicate structure which grows

from little sacs in the true skin called "follicles," and passes through the scarf-skin.

Each hair possesses a root and a shaft, and has glands which convey a greasy matter into it. When examined under a microscope, the hair is found to consist of numerous cells, such as we have seen in the skin, but these are pressed together lengthwise, so as to be drawn out into fibres, instead of being flattened into scales. In some of these cells the colouring matter is contained, while those on the outer surface form a sort of bark, overlapping each other something like the slates of a house. Thus, if you draw a hair between your fingers, it will feel smooth if drawn from root to point, but rough if drawn the reverse way.

The hair is nourished by the capillaries in the cutis, and when the circulation in this is defective, the hair dies and falls out. In the same way the colouring cells may become dried up, and then the hair turns grey or white.

The Sense of Taste.

The sense of taste seems to be an altered form of that of touch, for when certain substances touch the tongue, we not only *feel* them, but enjoy the additional sensation of taste. Taste is not, however,

centred in the tongue only, but in the palate and back parts of the mouth.

Only substances which can be dis-solv-ed can be tasted, and further, the tongue must be wet, otherwise it cannot transmit the sense of taste. Thus the saliva assists in enabling us to taste our food, and, as you have already been told, the saliva pours into the mouth the moment the tongue is touched.

The tongue consists of a large number of muscles, by which it is enabled to move in the various ways required for turning the food about during mastication, and, as you will remember, in drawing back so as to close the opening of the larynx.

Nerves are distributed over the surface of the tongue, which terminate in "taste organs," and it is when these are touched that the sense of taste is excited.

The Sense of Smell.

The sense of smell too, is in a degree allied to that of touch, in a manner which you will understand when the structure of the organ has been explained to you. Of course you know that this sense is seated in the nose, which is lined with a delicate membrane on which the fine threads of the nerve of smell (called the Olfactory nerve) are spread out.

Now you must know that those substances which can be smelt, are such as give out odorous (or smelling) particles; and these finely divided particles, floating in the air, come in *contact* with the lining membrane of the nose, as the matter to be tasted comes in contact with the membrane of the tongue. Now here again there is a resemblance between the taste and smell, for unless the lining of the nose be moist, the smell is not perceived. To meet this demand, the lining consists of *mucous* membrane, that is, a membrane supplied with a fluid which keeps the surface wet. When, however, this mucus is too plentifully supplied, as during a severe cold, the sense of smell is diminished, owing probably to the odorous particles being washed away.

The Sense of Hearing.

This sense takes its rise from the circumstance that when two bodies come into contact, or even when one body is forced rapidly through the atmosphere, the air *vibrates*, or shakes, so as to rise or fall into waves, and hence such movements are called *undulations* (from the Latin word "unda," a wave). These waves of sound strike against a membrane, called the membrane of the Tympanum, causing it to vibrate in various degrees according

to the impression made on it by the undulation of the air, and thus the impression is conveyed to the brain. The science which fully explains this wonderful process is called *Acoustics*, and I hope you will at some future day enter upon that interesting and delightful study.

The external organ of hearing, called the **Ear**, is formed of cartilage, covered with skin, and its purpose seems to be to collect the sounds. These pass down the canal in the temporal bone, across the bottom of which the membrane of the drum is stretched. At the back of this membrane is a hollow, called the **Cavity** of the **Tympanum**; this communicates with the throat by a canal, called the **Eustachian Canal**, of which you have already been told. Now the purpose of this is similar to the hole which you no doubt have observed in the side of a drum, namely, to give air to the inner side of the parchment stretched across the heads; for if the air in the drum were compressed it could not vibrate, and the sound would be almost as dull as if striking a solid mass. You will understand this if you strike a tumbler with a spoon when its mouth is turned downwards, so as to *shut in* the air, and if you afterwards turn the glass upwards, so as to allow free action of air on each side of the walls; even if you hold your

finger on a bell whilst striking it you interrupt the vibration, and the sound is altered.

The purpose of the Eustachian tubes then is to give air to the cavity of the tympanum, so as to allow of free vibration, and thus when we suffer from severe cold in the throat, we at the same time become temporarily hard of hearing, and often have ear-ache.

Within the cavity of the tympanum are three very small bones, called the **Malleus**, or hammer, the **Incus**, or anvil, and the **Stapes**, or stirrup—each being named from their resemblance to the object mentioned.

Two of these bones are connected by a *very* small one called the "orbiculare"—*very small* seems hardly to express *how* small these bones really are, for altogether they only weigh a few *grains*, the stapes, the *largest* of the tiny lot, being *one-sixth of an inch long*, and yet they are perfect in all their parts; they are supplied with a periosteum (the membrane surrounding the bones), have their blood-vessels and synovial capsules (*see* pages 8 and 33), just the same as the largest of the bones, and lastly, they have accurately acting muscles, which cause the little string to work on the membrane of the tympan at the one end, and on the Fenestra Ovalis (or oval window) at the other.

The "oval window" leads to a cavity, termed the **Labyrinth,** from its complex arrangement. The labyrinth consists of the Vestibule, the Semicircular canals, and the Cochlea, and from the cochlea the nerve of hearing, called the Auditory nerve, proceeds.

The Sense of Sight.

This sense is, as of course you know, seated in the eyes, and I will proceed to explain the construction of one of the eye-balls. The eye-ball, though generally considered *globular*, is not entirely so, as it has a projection in front. The rest, however, is globular. The wall of the eye-ball consists of three coats, namely :—

1. The **Sclerotic,** which is the external coat, and forms the "white" of the eye. It covers the entire globe, excepting in front, where an opening is left for the **Cornea.** This is a hard transparent projection in front of the eye, somewhat of the shape of a watch-glass. It is bevelled off at the edge, and fits into the aperture of the sclerotic.

2. The **Choroid,** which lines the sclerotic, is of a dark colour, and in the front forms radiating folds called the **Ciliary processes.**

3. The **Retina,** which is simply the optic nerve, or nerve of sight, which pierces the sclerotic

and choroid coats, and spreads into a membraneous form. At the spot where it enters there is no sense of sight, and it is therefore called the "blind spot."

In the front of the eye, and at the back of the cornea, a sort of muscular curtain is seen; this is the **Iris**, or coloured part of the eye, pierced by the circular opening called the *pupil.* The space between the iris and the inside of the cornea is called the Anterior chamber, and the space at the back of it is called the Posterior chamber, both of these being filled with a liquid called the **Aqueous** (or watery) **humour.**

Immediately at the back of the posterior chamber is the "*Crystalline Lens;*" this is a small but firm body, and its shape is *double convex,* that is, it is of a roundish shape on both sides, as if two watch-glasses were joined by their edges—but not equal glasses, for the back part of the lens is more round than the front; it is made up of several layers of very delicate fibres, and is enveloped in a transparent membrane, called the "Capsule" (or bag) of the lens. The large portion of the eye-ball at the back of the crystalline lens is filled with a jelly-like matter, called the **Vitreous** (or glassy) **Humour.**

Now let me, without entering deeply into detail of the subject, tell you in a very few words *why we see.*

You will remember that I told you, that when

an object is struck the blow shakes the air, and the waves cause the membrane of the ear to vibrate, and thus the sense of hearing is conveyed by the aural nerve to the brain; and that certain matters give out smelling particles, which, coming in contact with the lining membrane of the nose, induce the sense of smell to be conveyed by the olfactory nerve to the brain.

Now, similarly, the moment light strikes on any part of an object, it is reflected from every part of it, the rays so reflected passing through the crystalline lens, and, undergoing various modifications, are gathered on the expanded retina and are conveyed by the optic nerve to the eye.

The eye-ball is moved by various muscles, and rests in the orbit on a considerable quantity of fat, which forms an elastic cushion on which its movements can be freely performed.

The eyes are protected by the eyelids, which are rendered still more useful as a shade by the delicate fringe called the eyelashes, and they are kept moist by the liquid which flows from the lachrymal gland, which has already been described (page 13).

Further information on light in connection with colour is given under the head of "How to Colour your Drawings," in another volume of this series, called "Right Lines in their Right Places."

THE MICROSCOPE, AND HOW TO USE IT.

WHAT IS A MICROSCOPE?

EVEN the most unobserving person knows that he sees objects more distinctly in their details in proportion as they are near to him; and less clearly as they are distant from him. The page of a book (for example) of which he could not make out a single word from the farther end of a room, he can read, without much trouble, when a yard off; and with the greatest ease, when he holds it about a foot from his eyes.

In this case no more minute examination is needful; but if he were looking at a flower, which at a distance appeared only as a yellow spot on the green turf, he would find that on bringing it still closer to his eye than it would be needful to hold a book in reading, he could see (though not without soon wearying his sight) the form and structure of the various parts with a distinctness that would both interest and surprise him. But he would also discover that he could not (unless he were "short-sighted," or incapable of distinct vision at a distance) bring it *very* near to his eye, without losing all clear sight of it, and seeing only a misty and confused blur.

Were it possible to bring the object closer to the

eye, and to retain the faculty of distinct vision, much more of its parts and structure could be discovered, as a very simple experiment will show you. Take a minute insect, or a part of the more delicate organs of a flower, and hold it in a pair of tweezers, or the forceps of a microscope ; then having made a clear pin-hole in a card, hold it close to your eye, and the object you have chosen between it and the light, and you will find that, when no more than an inch from your eye, you can see it with perfect distinctness, and consequently so much larger, that you can perceive peculiarities in its appearance, &c., the existence of which you had not even suspected before.

This is, however, but an imperfect and unsatisfactory means of bringing minute objects sufficiently close to the eye ; and the same results can be obtained with far greater clearness by the employment of a lens, because it allows you to see the object with the light shining *on* it, instead of shining *through* it, and with far less weariness to the eye. There is, too, no assignable limit to the advantageous use of lenses ; whereas, you can never see an object clearly by means of a pin-hole in a card, when at much less distance than an inch from the eye.

A lens, thus employed, is (properly speaking) a microscope. It is commonly called a *magnifying glass*, because it makes the objects you look at through it seem larger. This is owing to its form—circular, and thicker in the middle than at the edges, so that one or both sides seem to be portions of a globe or sphere—which exerts on the rays of

light passing from the object into the eye a very remarkable influence, bending them so that the object seen through it appears when (say) two inches distant from the eye, as large (and far more clear) as when only one inch from the eye, and seen through the pin-hole in the card. This influence is called *refraction*; and it varies with the form and substance of the lens, so that in some instances its effect much exceeds what I have just stated.

Lenses, as you will readily perceive, can be made with one side flat, or with both sides spherical; and even with one spherical and the other hollowed. The first kind is called *plano-convex*; the second, *double convex*; the last, *concavo-convex*, or *meniscus*. The sphericity also, it is as easy to see, can be increased till the lens is a perfect globe, or till one side is a perfect hemisphere; or diminished until it differs little from a plane, or absolutely flat surface. The more nearly both sides approach to plane surfaces, of course, the lower will be the magnifying power; and the more convex they are, the higher it will be; as you are well aware, for you must have heard of this from old persons who use spectacles and reading glasses.

There is this difference between reading glasses or spectacles, and magnifying glasses or microscopes:—the former are used only to correct the indistinctness of vision which has been produced by age; whilst the latter are intended to give increased power and distinctness of vision, even to the best sight. For the first purpose therefore, it is not

needful that the glass should be wholly free from defects, and the surface mathematically accurate; but it is needful that lenses used for microscopic purposes should be as correct and of as pure glass as possible; and as these can be attained with greater certainty in a small lens than in a large one, most of the lenses used in microscopes, and all the important ones, are small. For it has been found that by using several lenses together, and intercepting the passage of the light through all but the central portion of them (to correct a defect, called spherical aberration), similar results are obtained to those obtained by the use of an exceedingly convex lens, and even to a much higher degree, and with far greater accuracy.

Until a very few years ago, microscopes, which had the least pretensions to be regarded as *scientific* instruments, were so exceedingly costly, as to be practically out of the reach of all but the wealthy, and those whose professional engagements made the possession of one indispensably requisite.

There were cheap microscopes, it is true, but they were only toys. And even as toys, little praise can be given to them, for they were not easy to use, and were very easily put out of order; and most frequently they exhibited the wonders of the microscopic world in such a way as to afford neither amusement nor instruction. If a better class of toy-microscopes exists now, it is entirely owing to the Society of Arts, which, by encouraging the production of a really cheap and yet scientific class of

instruments, has raised the character and quality of even the humblest and cheapest that are manufactured.

Remotely, we are indebted to the Great Exhibition of 1851 for the Prize Microscopes of the Society of Arts; for the want of cheap scientific instruments was first felt in consequence of that astonishing collection of the works of human skill and intelligence; and it was at the Educational Conference of the Society of Arts, which followed as one necessary supplement to the Great Exhibition, that the consciousness of this want was first expressed, together with the hope that it might ere long be supplied.

HOW TO WORK WITH THE MICROSCOPE.

Even those who regard the Microscope merely as an amusing toy will be benefited by some general directions respecting the use of it; and will not only be able to derive a greater amount of entertainment from it, but also to advance to such an employment of it as it deserves. And they may be assured that the greater interest in an instrument like the Microscope will always be felt by those who know what it can do, and who endeavour to obtain all the knowledge which it can disclose.

For those who desire to make the best use of this instrument, when they begin to work with it, some directions and instructions may be requisite, to enable them to avoid mistakes, and to profit by the experience of those who have studied the Micros-

cope and its uses, so as the sooner, and the more surely, to derive profit from their work. Whilst, however, I address myself principally to such microscopical students, others, who aim at entertainment alone, may be benefited and assisted; and therefore I invite their attention, also, to this chapter.

The first and most important direction to be observed is, never to subject your Microscope to rough usage. It is made strongly, for the prevention of accidents, but it should be used gently, for there is often damage done to an instrument which does not show as an outward flaw or fracture. Even for educational purposes, a Microscope should work perfectly and steadily in all its parts; have its lenses free from material blemishes, and perfect in their position as to centering, &c.; whilst for scientific research it cannot be too free from injury or defect in these particulars.

In taking it out of its case, therefore, and in putting its parts together, and especially in putting in and taking out the eye-pieces, and in screwing on and unscrewing the object-glasses, handle every piece as if you knew the value of the whole. Do not be in a hurry. The time that careful use of a Microscope requires is always well spent. The experience of all opticians shows that very many more instruments are spoiled or destroyed by carelessness than by fair wear or accident; and the maker is always blamed for damage which no care of his could prevent.

Hardly less important is the direction to keep

every part, and the lenses especially, scrupulously clean. The case, the drawer, and the brass boxes for the object-glasses, are supplied for the express purpose of enabling you to put the instrument as far as possible out of the reach of the very fine dust which flies about in every house. But if you have a place of safety for it, a bell-glass to cover the whole Microscope, together with all its accessories, is most serviceable, as it is then always ready for use.

Whenever it is requisite, wipe the stand, and the stage, and all parts of the instrument; and occasionally even the interior (but this you should do most gently) of the tube, of the eye-pieces, and even of the object-glasses, because small particles of dust may have settled there, and are easily transferred thence to the lenses. A camel's hair pencil, or a piece of wash-leather, is the best means of doing this; but you must not use the same wash-leather for these parts and for the lenses.

Always wipe the mirror and keep it bright, for upon its clearness depends the quality and the quantity of light you have for your investigations; and without sufficient and clear light, I need not say, you cannot succeed.

To ascertain if the lenses need to be wiped, look through the instrument when you have illuminated the field as brilliantly as you can. If there are any specks, take off the cap of the eye-piece, and gently wipe the outer surface of the glass nearest the eye; the under surface of the field-glass may also be

wiped in the same manner. If more is needed, carefully unscrew the lenses one by one, wipe each, and replace it immediately. It is better not to have two lenses unscrewed at the same time ; and most important not to have those of both eye-pieces, lest you should screw any one of them into the wrong tube in replacing them.

Still greater care must be exercised if it should appear that the dust has settled on the object-glass ; and it would be better not to separate the two inner lenses, but after drawing off the front lens to take the other two off together, and remove the dust from the upper surface of the innermost lens, replacing them immediately.

Notwithstanding all your care, it will sometimes happen that the outer lens of the object-glass will be wetted with the fluids you may be using on the stage. This should be wiped off at once, and completely. And you should never touch any of the lenses, nor place your hands too near them, because the insensible perspiration of the skin will condense on and dim them. And it will sometimes happen that the imperceptible moisture in the air will, in the same way, condense on the lenses and render them dull ; in these instances it is best to remove the eye-piece or object-glass rapidly backwards or forwards, or to place them where just sufficient warmth may reach them to cause this dampness to evaporate.

As a general rule, if there be any imperfection in the object-glass which you cannot understand, it

will be the safest and the surest course to have it remedied by the maker of the instrument, or some skilful optician: for your own attempts may irremediably damage it, or some of the lenses.

When you have occasion to lay down any one of the lenses of the Microscope beside you, whilst you are using the others, lay it with the milled edge downwards, that the under side of the lens may not be scratched or soiled. And so with the object-glasses, or the cap from either of them; set them lens uppermost on the table. Above all, do not lay these on their sides, as they may roll against some other part of your apparatus, or even fall from the table, in which case they could hardly escape injury. Whenever you can, put them away into their boxes, as soon as you have finished your work with them; and keep them there at all times when they are not actually in use.

The brass work of the instrument should be kept bright and clean by careful use; if, however, any part of it become tarnished by the fumes or contact of any acid, it may be cleaned by a very small quantity of rottenstone.

You will be wise not to meddle with any of the small screws which you see in various parts of the instrument. If you do, you must not blame the maker for the damage which, by your unskilfulness, you may do to your Microscope. Sometimes, however, by turning a very little one way or the other the screws in the plate which keeps the pinion close to the rack, behind the pillar, you can make your

instrument work more freely, or more steadily, as may be desirable. And in other respects slight alterations and improvements may be made by one who is acquainted with the instrument, and with the tools he employs.

For almost all these varied uses, the best mode of working with this little instrument is, to place it on a steady, and not very large, table, and to seat yourself so that you can without difficulty bend your head completely over the instrument.

Let the window (if you are working by day) be at your left hand; the position of the lamp is less material. Take out of the box the instrument and all the apparatus, placing the lenses with the milled heads downwards conveniently before you on the right hand, with the forceps, &c., and your object to be examined in the same manner on the left. Then screw the pillar firmly into the top of the box, and when it is fixed set it with the stage away from you, that you may have the benefit of all the light which you may require, both on it and on the mirror.

Now place on each side of the instrument three or four books, piled one on another, so as not to slip, nor move more than to follow the slight movements of the wrists, which are to be supported on them. Your elbows resting firmly on the table, and your wrists being thus supported, you can present and move or dissect your object on the stage without the least unsteadiness of touch, and so as to see or do with it precisely what you desire.

All that you require in addition to the adjuncts supplied with the Microscope are a fine and sharp-pointed pair of scissors; a pen-knife possessed of the same qualities, or a dissecting knife; and some needles of different sizes mounted in crochet handles. Needles are easily mounted by taking a stout cedar stick for a camel's hair pencil, and, holding the needle firmly in a pair of pliers or hand-vice, thrust it, eye foremost, a little way straight into the cedar stick; turn it about a quarter round and thrust it farther; turn it again, and so till it is firmly fixed. A camel's hair brush or two, and a small dipping tube, or rod of glass, will complete your apparatus.

If you are examining an object by transmitted light, you must turn the mirror so as to throw the rays directly upwards; and it is best to obtain the light from a white cloud, rather than from the blue sky, or the sun itself. Yet the direct light of the sun may be employed by reversing the mirror, and using the white plaster back, which will then supply a very cool and agreeable illumination. And whenever less light than you obtain from a white cloud by the mirror is required, you may use the back instead of the concave surface. And as I mentioned, by a very simple contrivance you may obtain a very good oblique illumination, which is sometimes very desirable.

But if it be an opaque body, then you must fix the condenser into its place, and turn it (with its plane side towards the object) so that the light (which must not come directly from the sun) shall

be concentrated on the object. When the three lenses are used in combination, the condenser cannot be brought to bear upon an opaque object, but in that case the reflector can be employed in its place, with the same effect.

Respecting the lenses, a little experience will soon enable you to judge which power of the seven at your command is the best for your purpose; and in every instance you should commence with the lowest power that seems likely to be sufficient; and when you have ascertained as clearly as you can the general form and appearance of the object, proceed to examine the several parts more minutely. And always remember, in using two or three lenses together, to place the lens of the highest power next the object, and that of the lowest power next the eye.

After having concluded your examination, you should carefully remove all dust, damp, &c., from the lenses, stage, &c., and put every part of the Microscope away into its proper place in its box.

*** *For list of prices of Instruments specially made for and supplied by the Publishers of this volume, see page* 125.

QUESTIONS FOR EXAMINATION.

1. What are the substances of which Bone is principally formed?
2. Where are the Haversian Canals, and what is the purpose of them?
3. What is the position of the Periosteum, and what purpose does it serve?
4. Name the bones forming the Skull, and describe their situation.
5. How are these bones joined?
6. Of how many bones does the human Vertebral Column consist?
7. Of these how many are movable, and how many fixed? Classify the Vertebræ according to their position.
8. How are the bones of the Spinal Column protected from injury which might arise from jumping or sudden shocks?
9. What is there peculiar in the motion of the Lower Jaw in man, and how does it differ from that of squirrels, cows, and cats?
10. Describe the Ribs, their number, structure, and purpose.
11. Where are the Clavicles, and what purpose do they accomplish in Man?
12. Where is the Humerus, and what bones are joined to it?

13. How does the joint at the top of the Humerus differ from that at the bottom ?
14. Describe the movements of the Radius on the Ulna.
15. Describe and sketch a single Vertebra, and explain why there is a hole through one part of it.
16. Describe the bones of the Leg, and compare them with those of the Arm.
17. Describe the human Hand and Wrist, and compare it with the Foot and Instep.
18. Where are the Orbits, and what apertures open out of them ?
19. What is the Thorax, and what organs does it protect ?
20. Name the Bones forming the lower part of the Trunk, and also the Bones which work in them.
21. Besides Sutures, by what other joints are Bones connected ? Give specimens of each.
22. How do the Hands and Feet of man differ from those of monkeys ?
23. Give a list of the Bones of the Arm and Hand, and another of the Leg and Foot, and show how they correspond with each other.
24. What is meant by "Dislocation" ?
25. How are the Movable Joints kept lubricated ?
26. How are the Bones of the Skeleton moved ?
27. What are Voluntary and Involuntary Muscles ? Give an example of each.
28. How are the muscles arranged, so that the movement caused by one, may when desired, be counteracted by another ?
29. What is the name of the muscle which bends a limb, and of the one which straightens it ?
30. What are Tendons ?

31. By what means are the Tendons confined at the wrist and ancle?
32. What is the effect of exercise on any muscle?
33. What is a Lever? how many kinds are there?
34. Show where each of the various kinds of Levers are applied in our bodies.
35. Describe the structure of a human Tooth.
36. Sketch and classify the human Teeth, and give the Dental formula.
37. Describe the process of Digestion in the simplest form of Animal life.
38. When food is placed in our mouth, what is the first process to which it is subjected?
39. Where are the Salivary glands, and what is their action during mastication?
40. How many Salivary glands are there? Give their names, and describe their positions.
41. When the food has undergone the process of Insalivation, what becomes of it?
42. What is meant by food "going the wrong way"? and how are we protected against such an accident?
43. Illustrate the last two replies by a sketch.
44. Where is the Cardiac Orifice, and where the Pyloric?
45. What is the Gastric Juice, where is it formed, and what is its effect?
46. Describe the process of Digestion as far as it proceeds in the Stomach.
47. How has the action of the Stomach been accurately observed?
48. Which takes longer to digest—Animal or Vegetable food?
49. How does the Intestinal Canal in a sheep differ from that of a tiger?

50. Why is "bolting" food, or taking too much, injurious?
51. Through what opening does the food pass from the Stomach, and by what name is the liquid known?
52. Where is the Duodenum, and by what means is a change effected in the food when passed into it?
53. Besides the two juices named, mention a third which effects the final change in the proceeds of digestion.
54. By what name is the liquid known when these three juices have acted upon it?
55. By what means are the proceeds of digestion gathered and made of use to our bodies?
56. Describe the principle of Endosmose, and show how it is applied in our system.
57. Describe the action of the Lacteals, the Lymphatics, and the Thoracic duct.
58. Describe "Blood Corpuscles."
59. What are Capillaries?
60. What are the three principal duties of the Blood?
61. Describe and sketch the human Heart.
62. Describe the lesser circulation.
63. Describe the greater circulation.
64. Explain the precise difference between Arteries and Veins.
65. Where are the following vessels, Aorta, and Vena Cava, and what are their duties?
66. Describe the Portal circulation.
67. Describe fully the movements of the Heart, and explain the means by which the Blood is prevented returning to the chamber from which it has been forced.
68. By whom and in what year was the Circulation of the Blood discovered?

69. Describe the Trachea and Bronchial Tubes.
70. For what purpose does the Blood circulate in the Lungs?
71. Describe the means by which that purpose is accomplished.
72. How do the Ribs assist in Respiration?
73. By what other means is the Thorax enlarged?
74. By what names are the processes of drawing in and expelling air called?
75. What is the name of the Membrane by which the Lungs are enclosed?
76. Describe the uses of Ventilation, and some of the principles on which it should be arranged.

    What are the causes of Sighing, Yawning, Sobbing, Laughing, Crying, Coughing, and Sneezing?
77. Describe the consequences of using tight belts, &c., round the waist, and also of stooping.
78. What is the Brain, and how is it divided?
79. Give the names and explain the uses of the Membranes which envelope the Brain.
80. What are Nerves, and how are the matters of which they are formed arranged?
81. What is the difference between the Cranial and the Spinal Nerves?
82. How many pairs of Cranial Nerves are there? Classify them according to their purposes.
83. What is the Spinal Cord?
84. How many pairs of Spinal Nerves are there? Classify them according to their position.
85. From how many roots do the Spinal Nerves arise, and how many pairs of them are there?

    What is meant by the Senses, and how are they named?

How does the Sense of Touch differ from all the other Senses?

86. Describe the Cuticle, and state its use.
87. What is the Rete Mucosum, and how does it affect the complexion of different races of men?
88. Describe the Cutis.
89. Where are the Perspiratory Glands, and what is the purpose of them?
90. Why is it dangerous to pass suddenly into cold air, or to plunge into cold water when perspiring?
91. Describe the structure of the Nails and Hair.
92. In which organs is the Sense of Taste situated? Describe the further uses of the Tongue.
93. Describe the cause of "Smell," and show how the sensation is conveyed to the Brain.
94. How are sounds produced?
95. What is the use of the Eustachian Tubes, and what passages do they connect?
96. Describe the Tympanum, the Malleus, Incus, and Stapes, and state their purpose.
97. What is the cause of Sight?
98. Describe (1) the Sclerotic Coat and Cornea; (2) the Choroid Coat.
99. Describe the Retina and Crystalline Lens.
100. How are the Eyeballs kept moist?

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